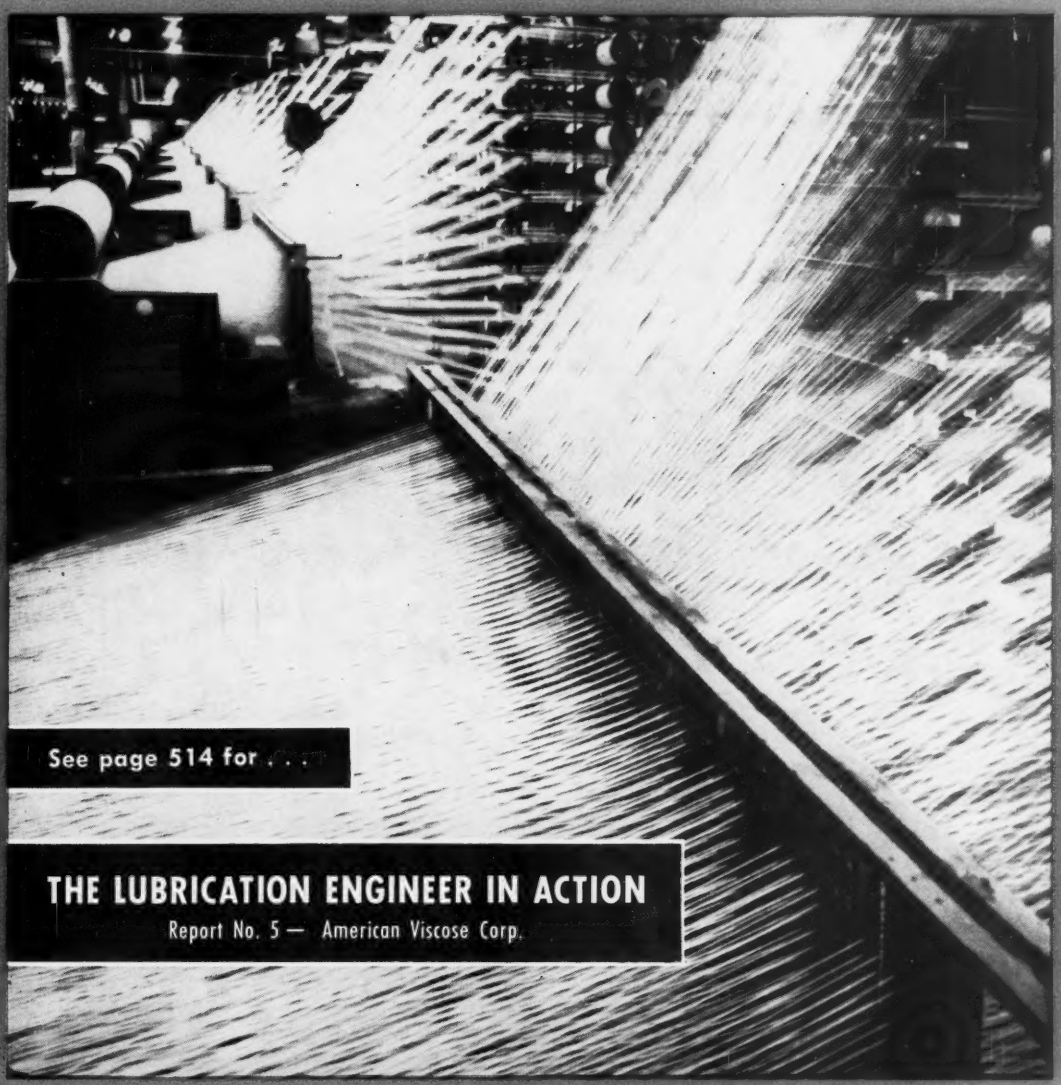
Vol. 16, No. 11 November, 1960

LUBRICATION ENGINEERING

DESIGN RESEARCH APPLICATION EDUCATION MAINTENANCE



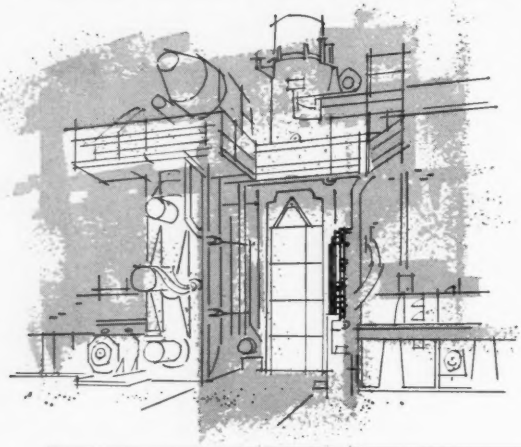
See page 514 for . . .

THE LUBRICATION ENGINEER IN ACTION

Report No. 5 — American Viscose Corp.

JOURNAL OF THE AMERICAN SOCIETY OF LUBRICATION ENGINEERS

ON INLAND STEEL'S 45" x 90" SLABBING MILL HEAVY DUTY FARVAL CENTRALIZED LUBRICATING SYSTEMS EASILY ADAPT TO BULK HANDLING

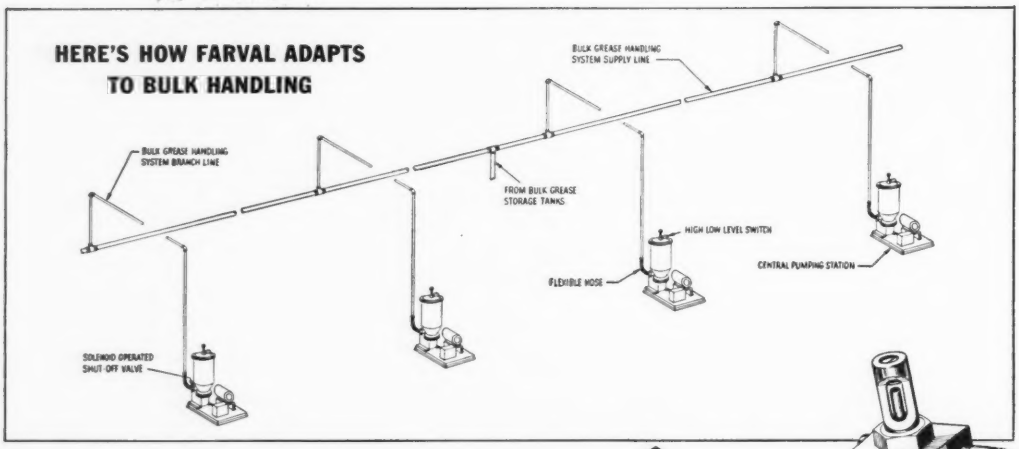


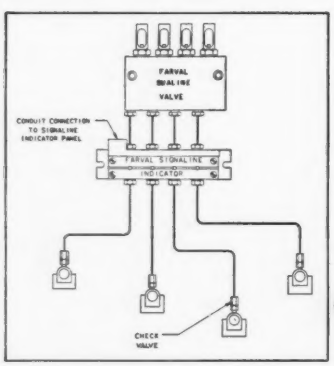
On Inland Steel's high production slabbing mill (shown at left) 1,023 bearings are served by 12 Farval Centralized Lubricating Systems. A single low pressure supply line connects each automatic central station reservoir to the bulk storage tanks—insures a constant supply of lubricant direct to bearings through individually operated Farval Systems.

On typical bulk handling installations (shown below), Farval reservoirs provide a reserve supply of lubricant for each system at all times. Manual or automatic controls can be provided for filling of reservoirs from the main supply line. System flexibility is assured by these Farval-engineered features—rugged double plunger units, automatic system timing controls and individual adjustable measuring valves with visual indicators.

With Farval on the job, indication is based on system performance . . . not on system failure.

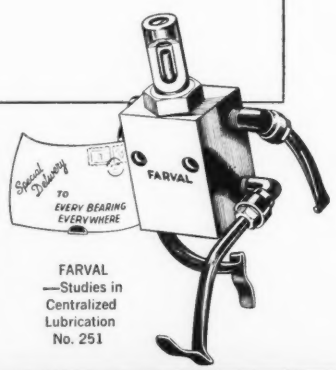
YOU ALWAYS FEEL SAFER WHEN YOU SEE THE FARVAL VALVES OPERATE.


HERE'S HOW FARVAL ADAPTS TO BULK HANDLING
BULK GREASE HANDLING SYSTEM SUPPLY LINE
BULK GREASE HANDLING SYSTEM BRANCH LINE
FROM BULK GREASE STORAGE TANKS
HIGH LOW LEVEL SWITCH
CENTRAL PUMPING STATION
FLEXIBLE HOSE
SOLENOID OPERATED SHUT-OFF VALVE



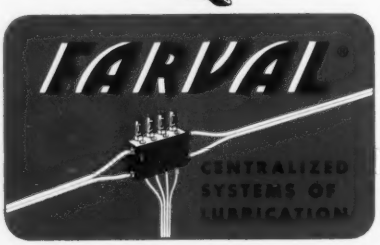
From bulk tanks to bearings—whether on a new installation or existing one—independently operated Farval Centralized Lubricating Systems can be easily tied into a common source of lubricant supply.

From bulk tanks, lubricant moves under low pressure through the main supply line to Farval reservoirs. Thus, use of this method avoids the dangers created in subjecting a large volume of lubricant to constant high pressure.



FARVAL
—Studies in Centralized Lubrication
No. 251

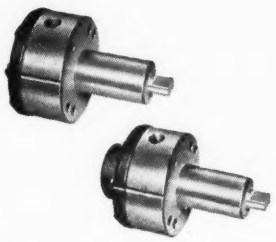
New Signaline Indicator—exclusive only with Farval—guarantees positive remote indication of broken or plugged discharge lines on critical bearings.



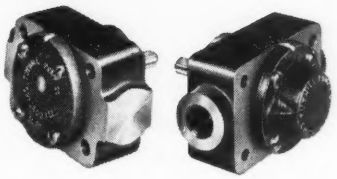
Farval Division · Eaton Manufacturing Company
3267 East 80th Street · Cleveland 4, Ohio

EATON

NOW! Have Reliable Lubrication at Minimum Cost

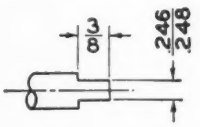


Models LF and RF
Capacities 55-170 g.p.h. at 1800 r.p.m.
Designed for flange mounting without shaft seal; with *choice* of internal or external porting. Model RF has automatic reversing feature which permits driving the pump in either direction... without changing direction of flow or port positions.

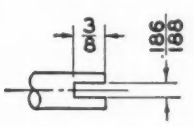


Models LFD and RFD
Capacities 60-180 g.p.h. at 1800 r.p.m.
Designed for non-directional service; for flange mounting with internal porting. Variations for external porting and/or shaft seal are shown below. Model RFD has the automatic reversing feature which permits driving the pump in either direction... without changing direction of flow or port positions.

ALTERNATE SHAFT DRIVE ENDS
For All Models



MODIFICATION "A"



MODIFICATION "B"

Tuthill "Cartridge-Type" Pumps Solve This Problem for Plant Maintenance...and Original Equipment Manufacturing

Durable—Reliable—and Available from Stock!

1. The demand for minimum cost lubrication pumps without sacrifice in performance, durability and reliability is *ideally* satisfied by the TUTHILL series of Models LF, RF, LFD and RFD *cartridge-type* pumps.

2. TUTHILL "cartridge" pumps get their reputation as cost-savers from their special design for original equipment use, their durable construction, their reliability...and the fact that they are *available from stock*. Note their compact size as shown in the photos above. Consider how all waste space has been eliminated for more adaptability. Think how they can be easily applied to your *own* requirements...in your plant...or in your equipment manufacturing plans.

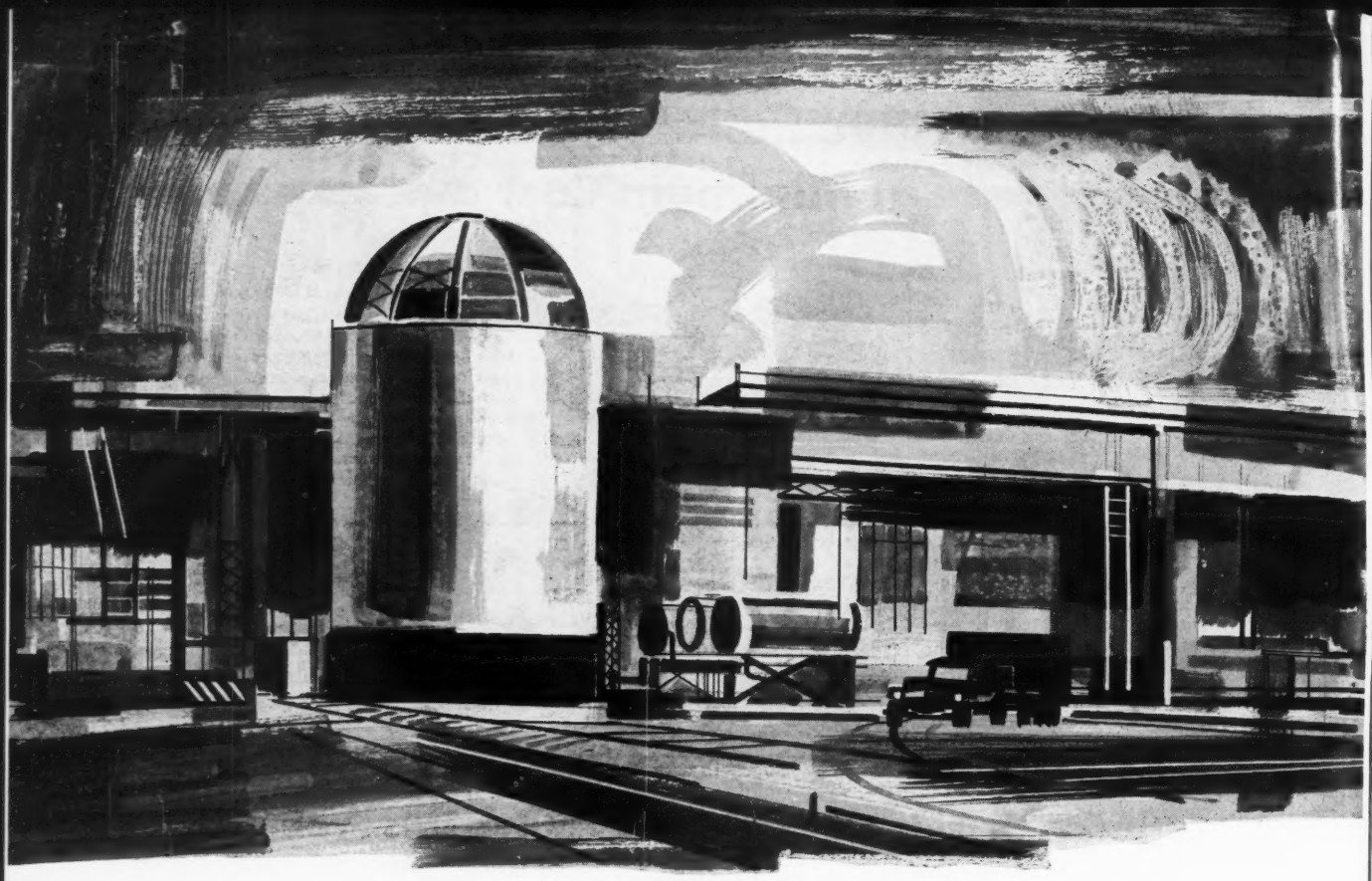
3. These variables are available:
- **a.** Pumps with...*or without*...automatic reversing performance
- **b.** Pumps with...*or without*...a shaft seal
- **c.** Pumps with internal...*or external*...porting
- **d.** Pumps with *variations* of both internal and external porting

4. TUTHILL Catalog Section 108 contains line drawings showing each model in detail, shaft rotation and porting arrangements and other vital statistics to help you select the RIGHT model. Fill out the attached coupon—or write.

TUTHILL PUMP COMPANY
.5th Street, Chicago 19, Illinois
Gentlemen:
☐ Please send me Catalog Section #108
☐ Please send the complete catalog on the Tuthill line
☐ Have your representative call
NAME_____ TITLE_____
COMPANY_____
ADDRESS_____
CITY_____ ZONE____ STATE_____

Tuthill Manufactures a Complete Line of Positive Displacement Rotary Pumps in Capacities from 1 to 200 GPM, for Pressures to 600 PSI, Speeds to 3600 RPM.

TUTHILL PUMP COMPANY
971 East 95th Street, Chicago 19, Illinois
PUMPS FOR YOUR PURPOSE



From a nuclear reactor...

to a delicate watch...

THE VERSATILITY OF MOLYSULFIDE® SOLVES MANY LUBRICANT PROBLEMS

On a nuclear reactor installation in England, it was proved that Molysulfide was the best lubricant to meet the exacting conditions of radiation and dry CO_2 at high pressure and temperature. Molysulfide in a resin carrier was baked on the ball- and roller-bearings used on the control rod mechanism of the reactor itself.

On the other hand, Molysulfide can be used in countless lubricants, from delicate watch parts to heavy-duty roll neck bearings . . . from self-locking nuts designed to withstand supersonic flight stresses to multi-purpose chassis greases.

There are five fundamental characteristics of Molysulfide which account for its unmatched excellence in lubricating applications:

- It has a very low coefficient of friction which decreases as load and sliding speed increases.
- It has a natural affinity for metal surfaces.
- It resists pressures far beyond the yield point of most metals.
- It is chemically stable.
- It performs over a wide temperature range from — 300 F to 750 F (over 2000 F in an inert atmosphere).

If you are faced with a tough lubrication problem, whether in research or in production, it will pay you to investigate the versatility of Molysulfide.

For a demonstration tube of Molysulfide, write Climax Molybdenum Company, 1270 Avenue of the Americas, New York 20, N. Y.

CLIMAX MOLYBDENUM

CLIMAX MOLYBDENUM COMPANY

a division of AMERICAN METAL CLIMAX, INC.

Lubrication Engineering

DESIGN RESEARCH APPLICATION EDUCATION MAINTENANCE

Contents

LUBRICATION IN PRACTICE

The Lubrication Engineer in Action
John K. Willcox at American Viscose Corp. 514
A Survey of Lubrication Methods
Part 3—Compendium of Lubricating Devices
(Continued) .....A. F. Brewer 519

RESEARCH, DESIGN, DEVELOPMENT

Relaxation Phenomena in
Lubrication .....E. O. Forster 523
Engine Rusting in Service and
Dynamometer Tests .....Paul A. Bennett 529

CURRENT NEWS

Lubrication in the News 497
Society News 508
Section News 511

EDITORIAL TOPICS

Review Procedure Charts for ASLE Papers 512
The Course of an ASLE Paper .....John Boyd 513

LITERATURE SUMMARIZED

Lubrication Abstracts 541
Patent Abstracts 542

TRADE INFORMATION

New Products 499
Product Literature 507
Advertisers' Index 544

Abstracted by Engineering Index and Industrial Arts Index

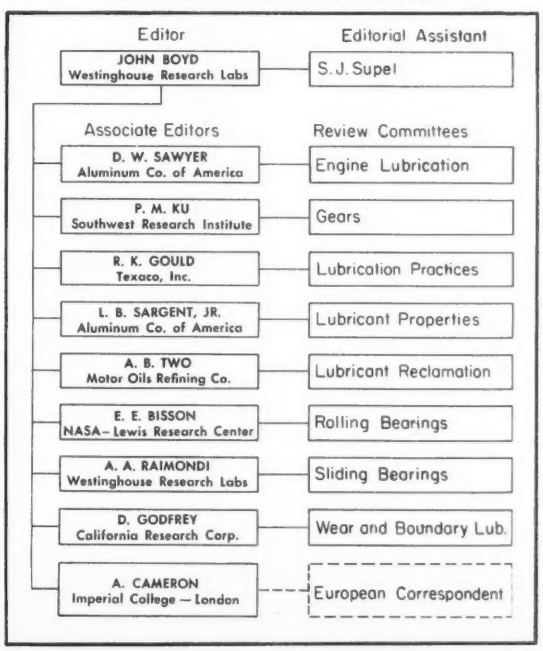
John Boyd, Editor
A. F. Brewer, Consulting Editor
Flo Shoemaker, Pubns. Manager
C. L. Willey, Executive Secty., ASLE

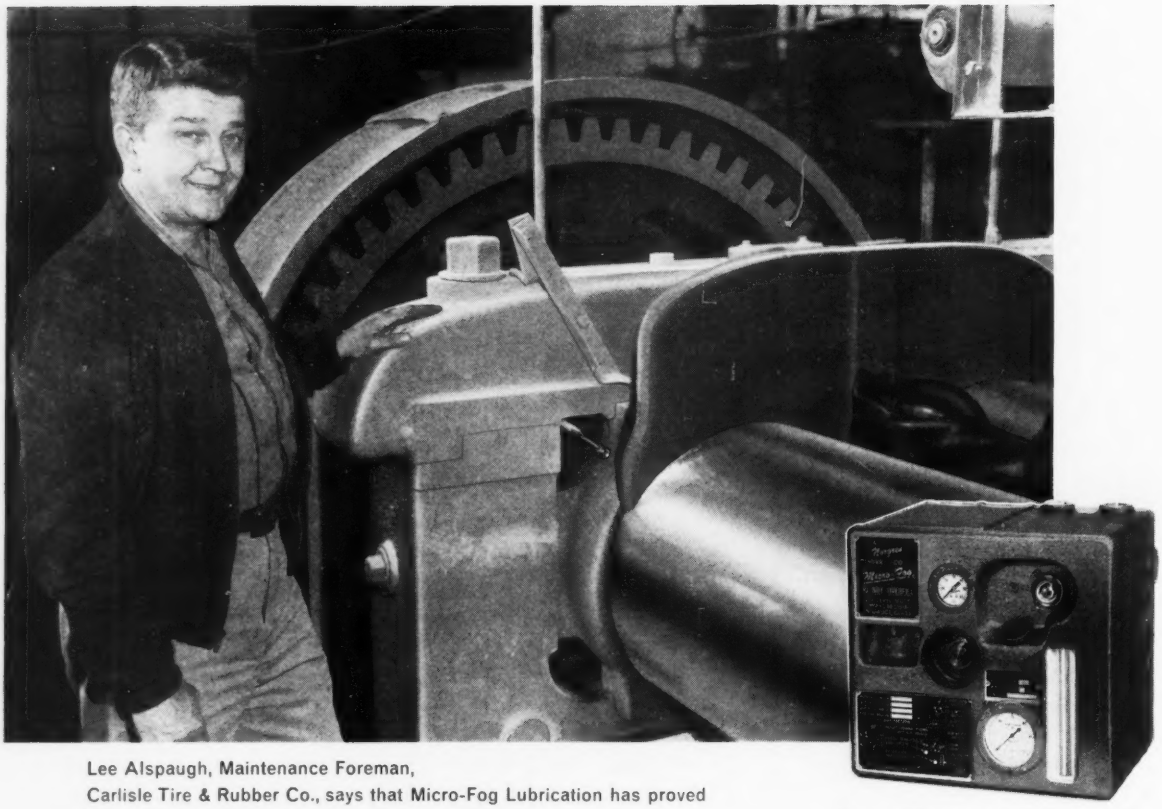
LUBRICATION ENGINEERING is published monthly by the American Society of Lubrication Engineers, 404 N. Wesley Ave., Mount Morris, Illinois. Current volume single copies 75¢, copies to foreign addresses add 50¢ per copy. Photoprints of articles prior to the current volume may be obtained from the John Crerar Library, 86 E. Randolph St., Chicago 1, Ill. Annual subscription $6.00 in the USA and Canada, $7.00 to all other countries.

Copyright by the American Society of Lubrication Engineers, 1960. ASLE will not be responsible for statements or opinions presented at its meetings or printed in its publications.

Second class postage paid at Mount Morris, Ill.

EDITORIAL REVIEW ORGANIZATION





Lee Alspaugh, Maintenance Foreman, Carlisle Tire & Rubber Co., says that Micro-Fog Lubrication has proved ideal for the bearings and gears on this warm-up mill.

Norgren Micro-Fog Lubro-Control Unit

Norgren Micro-Fog improves lubrication on heavy machinery at Carlisle Tire & Rubber

...minimizes housekeeping problems

At Carlisle Tire and Rubber Division of Carlisle Corporation, Carlisle, Pennsylvania, drip-feed oilers proved unsatisfactory for lubricating the gears and bearings of warm-up mills. Early in 1959, a Norgren Micro-Fog Lubro-Control Unit was installed on one of the mills. The unit lubricates the bearings for the 5′ long, 20″ and 22″ diameter rolls. It also lubricates the gears—a 63″ pitch diameter 12″ face bull gear with a 16″ pitch diameter 12½″ face pinion.

The Norgren Unit automatically and continuously applies an exactly metered amount of fresh, clean oil to each bearing and gear.

Carlisle reports that bearings run cooler and quieter, and wear on gears and bearings is now at a minimum. Less lubricant is needed, servicing is quicker, and messy housekeeping conditions around the machine have been eliminated. As a result, Carlisle is converting other critical machines in the plant to Micro-Fog lubrication.

Norgren Micro-Fog Lubrication gives you these money-saving benefits:

1. Automatic, continuous lubrication in exactly metered amounts
2. Better lubrication—less machine downtime.
3. Lubrication for all types and sizes of bearings, and for gears, chains and ways.
4. Fewer service points—centralized lubrication.
5. Lower bearing temperatures.
6. Longer bearing and gear life.
7. Lower costs for lubrication maintenance.
8. Low lubricant consumption—lower cost for lubricant.
9. Elimination of product contamination by lubricant.
10. Elimination of fire and safety hazards from dripping lubricant.
11. Visible oil feed.
12. Elimination of many oil seals.
13. Oil always fresh and clean—no recirculation.
14. Elimination of oil filters, sumps and pumps.

FOUNDED IN 1926

C. A. NORGREN CO.

3434 SOUTH ELATI STREET • ENGLEWOOD, COLORADO

For complete information about how Norgren Micro-Fog Lubrication can make big savings in your plant, call your nearby Norgren Representative, listed in your telephone directory—or WRITE FOR DESCRIPTIVE LITERATURE.

LUBRICATION IN THE NEWS

The Society will not be responsible for the accuracy of statements made in this column. Any reference to proprietary products does not imply an endorsement of such products by the Society.

BULK GREASE HANDLING FEATURED AT AISE CONVENTION

There was considerable interest shown at the 1960 Iron and Steel Convention and Exposition, held in Cleveland, September 27-30, in an expanding trend toward bulk grease handling in the steel industry. Among the exhibits were featured displays based on equipment now available for bulk grease handling.

A technical paper, entitled "Grease on Tap," was given by Charles A. Bailey, lubrication engineer, National Tube Division and Donald R. McCaa, product manager, Standard Products Dept., American Bridge Division of United States Steel Corporation.

The technical paper pointed out that increasing interest in bulk grease handling in steel mills is the result of improved lubricants, methods of application, and containers now available. Methods, practices, and container designs were analyzed to show how every mill can have "grease on tap." (Source: Assoc. of Iron and Steel Engineers).

DYNEX, INC. FORMS NEW DIVISION AND HOLDS CONFERENCE ON HYDROSTATIC TRANSMISSIONS

Dynex, Inc. ushered in its new "Systems Engineering Division" with a conference and demonstrations on Hydrostatic Transmissions. Over 125 executives and engineers watched high pressure hydraulics, engineered by Dynex, perform in special earth moving vehicles.

The conference was highlighted by a paper entitled "Hydrostatic Transmissions" which was presented by the new Systems Engineering Division Manager, Wesley R. Master.

Actual field demonstrations were given of the Corps of Engineers' Ballastable All-Purpose Tractor (B.A.T.) with hydrostatic traction assist; Caterpillar D-8 Tractor with hydrostatic creeper drive developed for snow compaction; and LeTourneau-Westinghouse Skid-Steer DW-2 Tractor equipped with hydrostatic steering which utilizes "Split-Flow" synchronization of each fluid motor drive. (Source: Dynex, Inc., Pewaukee, Wisc.)

COMBUSTION ENGINE MANUAL AVAILABLE FROM OTS

A Navy report on the maintenance and operation of internal combustion engines has been released to science and industry through the Office of Technical Services, U. S. Department of Commerce.

The report is: *Power Generation and Distribution*, Chapter 5—"Internal Combustion Engines, Maintenance and Operation." Bureau of Yards and Docks, U. S. Navy. Dec. 1953. 64 pages. (Order PB 161743 from OTS, U. S. Department of Commerce, Washington 25, D. C., $1.75.)

This operation manual for stationary internal combustion engines is on power generation and distribution. The series covers three basic forms of power: electricity, steam (and high-temperature water), and compressed air. Primary, alternate and emergency sources of power are described, and general features of power generation and distribution are discussed, as they apply to maintenance and operation. Chapter 5 covers the operation and maintenance of stationary internal combustion engines and discusses safety precautions, inspection procedures, trouble shooting, and engineering record keeping. The report lists performance curves for both gasoline and diesel engines, and makes recommendations concerning lubricants, fuels rust prevention, placement. (Source: O.T.S., U. S. Department of Commerce).

CHICAGO TO BE SITE OF 1961 PLANT MAINTENANCE AND ENGINEERING SHOW

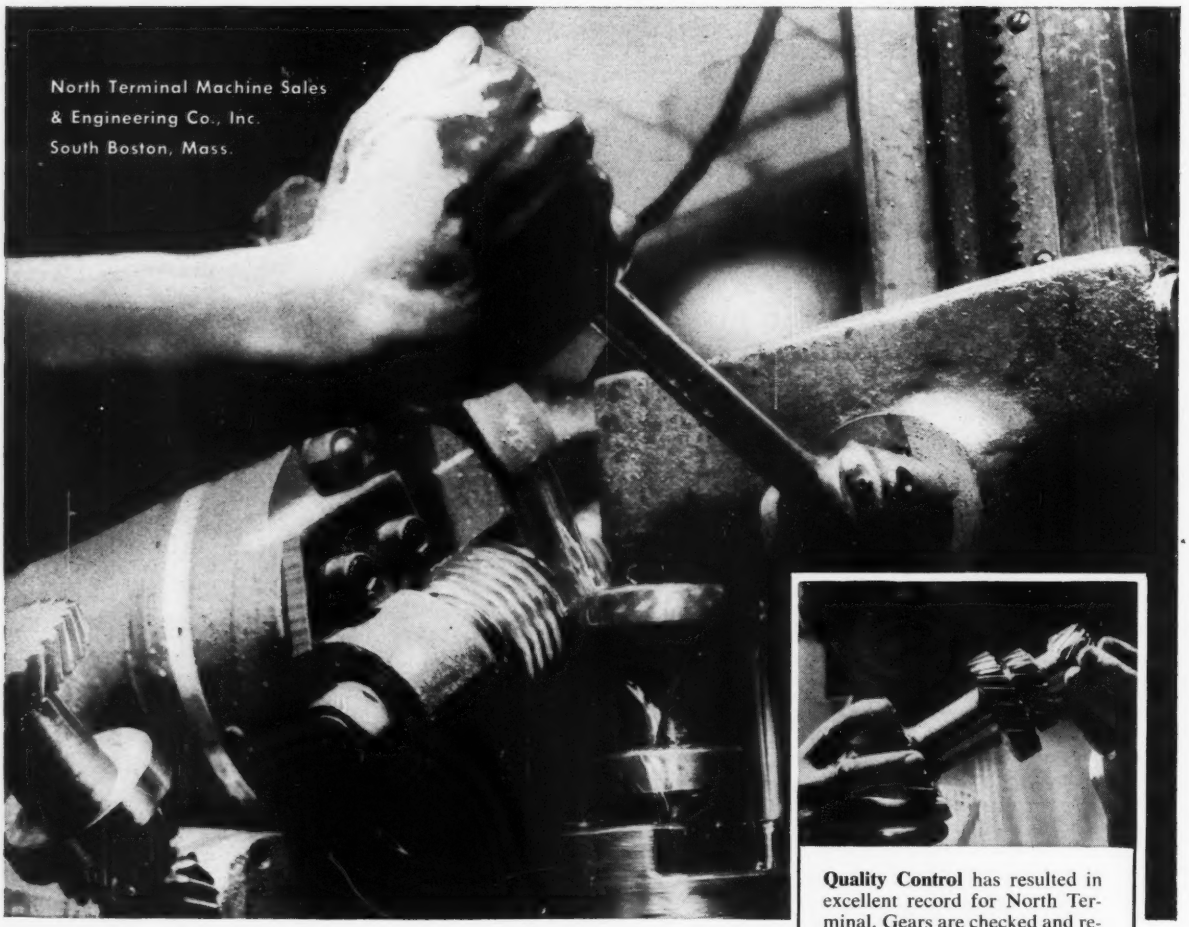
Chicago will be the site of the twelfth Annual Plant Maintenance and Engineering Show. The show will run for four days, January 23 through 26, 1961, at the International Amphitheatre. The conference will run for three days, January 23 through 25. Morning sessions of the conference will take place at the Amphitheatre and evening sessions at the Palmer House.

The 1961 exhibit area is expected to exceed six acres and about 375 companies are expected to participate as exhibitors. The theme for the 1961 show will be "The Maintenance Operation Meets the Needs of Increased Production." (Source: Banner and Greif)

IRON AND STEEL ENGINEERS ELECT NEW OFFICERS

Announcement of the new officers for the 8,000 member Association of Iron and Steel Engineers was made at the 1960 AISE Convention and Exposition held in Cleveland, September 27-30. C. E. Pritchard has been elected President of AISE. Mr. Pritchard, a former ASLE President and Director, is general superintendent of rolling mills for Alan Wood Steel Company. Other officers elected include H. L. Jenter (Vice President of operations of American Steel and Wire Div., U. S. Steel Corp.), 1st Vice President; C. W. Bruce (Chief Engineer of Steel Plants, Republic Steel Corp.), 2nd Vice President; H. R. Knust (Assistant General manager of Bethlehem Steel's Sparrows Point plant), Treasurer; and N. C. Michels (Vice President—Engineering, Tennessee Coal and Iron Div. U. S. Steel), Secretary. (Source: Association of Iron and Steel Engineers)

C. E. PRITCHARD

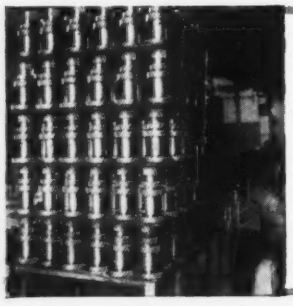


Quality Control has resulted in excellent record for North Terminal. Gears are checked and rechecked after each step in production. Quality lubricants have helped hold to close tolerances.

Hob Life Increased 250% with Cities Service Chillo 10 Cutting Oil

North Terminal makes replacement gears for automobile transmissions. In a day's time the firm—which makes the gears from raw stock to finished product—completes up to 5600 gears. Producing in quantities like this, hob life is an important consideration in *cost* of production as well as *quality* of production.

Previous cutting oils were tested on the gear hobbing machines and they resulted in hobs producing as low as 87 gears before replacement. Cities Service Chillo 10 cutting oil under the same conditions resulted in over 200 gears with a superior finish before a hob replacement was necessary.



5600 Gears per day or the equivalent of 800 replaced transmissions are produced every day by North Terminal. Gears are made for all makes of cars with a good portion of production being shipped overseas.

Edward W. Malley Jr., President of North Terminal, states, "We didn't choose Cities Service cutting oil blindly. Many competitive oils were tested before we were satisfied that Chillo 10 was superior in every way."

Even if you're satisfied with your present cutting oil, a test of Cities Service Chillo 10 may give you a very pleasant surprise. Test after test under actual manufacturing conditions has shown Chillo 10 to give longer tool life and superior finishes.

Arrange for your own test by calling your nearest Cities Service office or write: Cities Service Oil Company, Sixty Wall Tower, New York 5, New York.

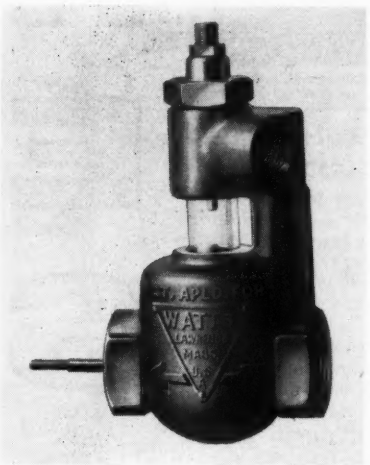
CITIES SERVICE

QUALITY PETROLEUM PRODUCTS

NEW PRODUCTS

NEW INJECTION OILER ANNOUNCED

Designed for use with low volume short stroke air cylinders, by the Watts Regulator Co., the new Watts No. 608 injection oiler is manufactured to provide a new type of mist-type lubrication.



Installed in the pressure line between control valve and cylinder, the injection oiler is designed to deliver a controlled amount of oil direct to the cylinder through a capillary tube within the cylinder air supply line. Oil is supplied to the injection oiler either from a standard lubricator placed ahead of the control valve or from a small oil reservoir under pressure.

Circle No. 1 on Reader Service Card

NEW HIGH VACUUM DIFFUSION PUMP OFFERS MAJOR IMPROVEMENTS

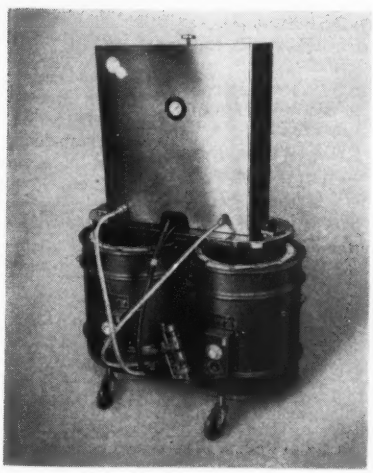
According to its manufacturer, NRC Equipment Corporation, the new 6-in. fractionating oil diffusion pump, labeled H6-1500, was designed especially to reduce operating and maintenance costs and to assure top performance even under unfavorable operating conditions.

The H6-1500 incorporates an improved boiler and a simplified fractionating jet assembly which has three diffusion and one ejector stage. The speed peaks at 1500 liters per second between 6×10^{-5} and 5×10^{-4} mm Hg, and is more than 1400 liters per second from 1×10^{-5} to 1×10^{-3} mm Hg. Fore-pressure tolerance is 700 microns at blank-off and 600 microns at full load. Backstreaming is less than 0.03mg/cm²/min. Blank-off, measured in a standard test dome with metal gaskets and untrapped ionization gauge, is 5×10^{-8} mm Hg. Used with an ultra-high vacuum test dome and liquid nitrogen cold trap, the H6-1500 has produced pressures as low as 2×10^{-10} mm Hg.

Circle No. 2 on Reader Service Card

NEW "DUO-FLO" EQUIPMENT ANNOUNCED

A new low-cost production machine for continuous pumping, metering and applying flowable two-part compounds has been announced by Pyles Industries, Inc., subsidiary of Kent-Moore Organization, Inc.



Called "Duo-Flo", the equipment is claimed to meter a wide range of two-part compounds 0 to 20,000 CPS viscosity, 5 parts per hundred to 50-50 epoxies, polyurethanes, polyesters, and foam. Features of the new equipment includes high volume capacity, internal mix, adjustable spray range and adaptability to 55 gallon drums.

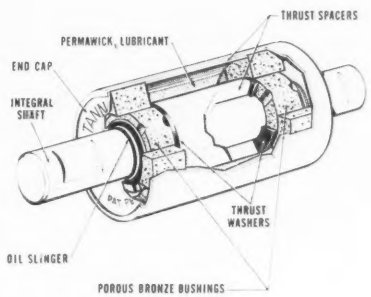
The manufacturer states that "Duo-Flo" is portable, simple to clean, and durably designed for production needs.

Circle No. 3 on Reader Service Card

NEW SHAFT-BEARING ASSEMBLY DESIGNED

A new shaft-bearing assembly, designed for quieter and longer life expectancy without re-oiling, is in production by the Tann Bearing Company, division of Tann Corporation, Detroit.

It is recommended for applications where bearing noise or conducted resonances are problems, as in packaged air conditioners or sheet metal ductwork, and in locations with high ambient humidity or abrasive atmospheres, as in home laundry equipment and industrial sanding or exhaust equipment.



The sealed bearing is reported to have a lifetime recirculatory oiling system which is highly resistant to invasion by dirt or moisture. Base life of at least 20,000 hours is predicted. The current assembly reportedly is designed to handle radial loads of 25 to 30 pounds at speeds of 500 to 4,000 rpm with moderate thrust loads.

Circle No. 4 on Reader Serivce Card

EXTREME PRESSURE ADDITIVE DEVELOPED

Ethyl Corporation has announced the development of a new extreme pressure additive, called Ethyl Extreme Pressure Additive 1. The new product has been developed for use in automotive transaxle fluids, in gear oils, and in industrial cutting oils. It is offered to meet severe "extreme pressure" conditions.

Circle No. 5 on Reader Service Card

NEW *EMRALON*® TFE COATINGS SOLVE HEAT SENSITIVE APPLICATIONS

Acheson's resin-bonded tetrafluoroethylene (TFE) surface coatings are finding ready acceptance among design engineers. Where previous limitations of pure TFE prevented its application on heat sensitive substrates, because of its 700° F. sintering temperature, 'EMRALON' coatings are being successfully used on rubber, light metals, woods, and plastic. One such impressive case history is outlined here.

'EMRALON' coating is shown being spray-applied on woven belting with conventional equipment.

OVER $15,000.00 ANNUAL SAVINGS PROJECTED BY PROMINENT TIRE MANUFACTURER

Dunlop Tire and Rubber Corporation, Buffalo, N. Y., estimates this considerable savings in down-time costs alone on the basis of nearly nine months production use of an 'EMRALON'-coated belt conveyor. The particular belt involved is thirty feet long. Its importance in this company's tire production is emphasized by the fact that it is located at the point of a previous bottleneck. Rubber strips, conveyed from a series of masticating mills to an extruding press, formerly became stuck to the belting of this short-run conveyor immediately above the final masticator. The reason: the temperature of the rubber is elevated — through friction of the masticating process — to between 150° F. and 300° F. at this point. Belts had to be replaced anywhere from once every several hours to every six weeks. It was not unusual to have two or three stoppages every shift. The result: with the supply of rubber temporarily cut off, the entire department shut down. Costs ran $5.00 a minute, and with these work stoppages averaging 20 minutes each, the accumulated expense became prohibitive. Since April, 1959, the new belt has been in constant operation at this critical point in the masticating line.

To date it has not been removed from the mill . . . ample proof of the extraordinary non-stick, adhesion and flexing qualities of its 'EMRALON' coating!

The woven conveyor belt is a product of Globe Woven Belting Company, Buffalo, N.Y. Application of Acheson's 'EMRALON' to their belting was the outcome of a continuing research program headed by Globe Research Manager, Fred Kohlhagen. It is applied by standard commercial spray equipment to a film thickness of 0.7 mils and then oven-cured at a temperature of 300° F.

According to Mr. Kohlhagen, "This example will be only one of many success stories told about this coating. 'EMRALON'-coated belting can be used anywhere a slick, non-corrosive belting is needed. Those in the baking, canning, food processing, food packaging, and rubber fields should find immediate use for it." We might add that there are many other industries finding it advantageous to use 'EMRALON' . . . yours quite possibly is one of them. Why not write today for further information?

'EMRALON' — coated conveyor belt carrying hot rubber through masticating mill.

'EMRALON' ADVANTAGES PROVED IN MANY LIGHT-LOAD USES

The growing list of production applications for the new Acheson 'EMRALON' surface coatings, is convincing proof of their versatility. That film pack, office machine, and lock mechanisms; rubber molds and oil seals; bakery dough handling equipment and countless other light load, solid-film lubrication problems have successfully been answered, is now a matter of record.

With 'EMRALON' 310* — colloidal TFE in a phenolic resin solution — a one-hour cure at 300° F. is all that is necessary. And, for substrates even more sensitive to heat, 'EMRALON' 320** colloidal TFE in a thermo-plastic resin carrier — is available. Both provide excellent adhesion, low coefficient of friction, flexibility, toughness, and corrosion resistance. Applied by conventional paint spray equipment, they allow easy production line conversion to 'EMRALON' solid-film lubricants.

'EMRALON' coatings represent the latest in a long line of widely accepted Acheson products, one of which may offer a ready-made answer to your particular lubrication problem. We welcome the opportunity to be of service. Send for your copy of our Products List which outlines the full line of Acheson Dispersions. Address Dept. LE-110.

*'EMRALON' 310 is manufactured under exclusive license from E. I. duPont deNemours & Company (Inc.) under U. S. Patent 2,825,706. Not licensed for use or for sale for use in providing electrical insulation.

**'EMRALON' 320 — patent applied for.

'dag' is a trademark registered in the U. S. Patent office by Acheson Industries, Inc.

ACHESON

dispersions digest reporting uses for

dag® BRAND DISPERSIONS

ACHESON *Colloids Company* **PORT HURON, MICHIGAN**

A division of Acheson Industries, Inc. Also Acheson Industries (Europe) Ltd. and affiliates, London, England

Offices In:

Boston • Chicago • Cleveland • Dayton • Detroit • Los Angeles • New York • Philadelphia • Pittsburgh • Rochester • St. Louis

take advantage of Lubrication Engineering's reader service department now!

Postage Will Be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD

First Class Permit No. 41874 (Sec. 34.9, P.L. & R.) Chicago, Illinois

LUBRICATION ENGINEERING

American Society of Lubrication Engineers, Publisher

5 North Wabash Ave.

CHICAGO 1, ILLINOIS

For your convenience . . .

LUBRICATION ENGINEERING'S READERS' SERVICE DEPARTMENT

. . . makes it easy for you to get more information about the items mentioned in the New Products and Product Literature Departments in this issue. Simply circle the numbers on the Readers' Service Reply Card that corresponds with the number under each item featured in New Products and Product Literature, drop the card in the mail, and within days you will receive the information requested.

November, 1960

LUBRICATION ENGINEERING'S READERS' SERVICE CARD

This card expires December 31, 1960

Please have information sent to me on items circled below:

1	2	3	4	5	6	7	8	9	10	11	12
13	14	15	16	17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32	33	34	35	36

My Name_____ Title_____

Company Name_____

Address_____

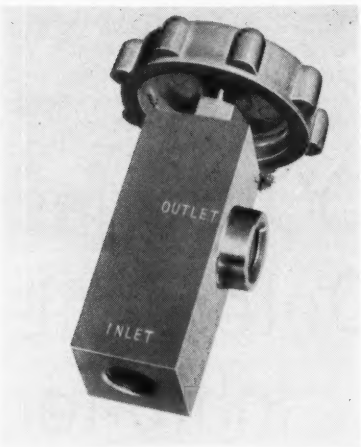
City_____ Zone_____ State_____

NEW PRODUCTS

(*Continued from page* 499)

LEAKPROOF HIGH PRESSURE SHUTOFF VALVE AVAILABLE

A new leakproof high pressure Shutoff Valve, featuring full-flow passage and foolproof O-Ring sealing, is now available from Circle Seal Products Co., Inc. This new valve, in the Company's 900 Series, is of right angle configuration for maximum mounting convenience. The R900 Valve has a single inlet and outlet; the Y900 a single inlet and two outlets; the Z900 two inlets and a single outlet.



Basic stainless steel construction of the new valve, coupled with a choice of O-Ring materials, permits use with practically any gaseous or liquid service medium. Either Buna N, Neoprene or Viton A O-Rings are available. Operating temperature range is from −40° to 450°F. Operating pressure range is from 0-6000 psi with zero leakage. All valves are proof-pressured at 7500 psi; burst pressure is well over 20,000 psi.

Structural features of the new Shutoff Valve provide for long maintenance-free service life. The unique Circle Seal design engages a precision machined stem into a resilient O-Ring for dead tight sealing of gases and liquids. A spring-loaded sleeve follows the stem as it is withdrawn. This sleeve encloses the O-Ring and protects it against extrusion and the cutting action of fluid flow. Stem and seat are designed to permit gradual throttling of flow as the valve is actuated. Only 20 inch pounds of force is required to actuate valve under full 6000 psi pressure.

Circle No. 6 on Reader Service Card

NEW MULTI-CHANNEL BLENDING SYSTEM DEVELOPED

An automatic controlled blending process of mixing ingredient components from a number of fluid sources into one stream, achieving a desired blend of constituent streams is possible with the Bendix-Pacific Computer.

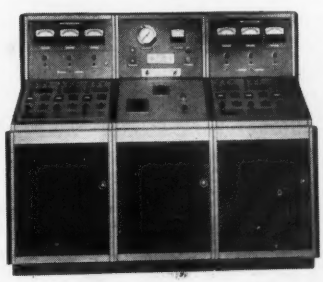
In the new system, all measuring and control elements are connected by wire for electrical exchange of information and control functions. The Bendix-Pacific computer controlled blending system operates accurately with equipment located wherever convenient.

Circle No. 7 on Reader Service Card

HYDRAULIC FORCE CONTROL CONSOLE MANUFACTURED

The new Gilmore Hydraulic System Control Console has been developed by Gilmore Industries, Inc. to provide accurate closed loop control on static and dynamic loading test stands.

Designed for up to 100,000 lbs. force capacity per cylinder, the system includes a load cell in series with each cylinder to provide the force feedback component to the console. An individual control on each channel allows stepless adjustment of cylinder force within 1% from 10% to 100% of the load capacity. A ganged master control provides simultaneous force control on all six cylinders. The master control can be manually positioned or programmed to produce pre-determined sequence of loadings on all channels.



The console includes jog and jog rate controls to manually extend or retract the cylinder piston at various speeds. Also included are hydraulic oil temperature and pressure indicators, pump motor controls, and hydraulic on-off controls including emergency dump control. Each channel has an alarm circuit to remove hydraulic pressure in event of a sudden 50% overload or a sustained 10% overload for a period of 20 seconds or longer.

Circle No. 8 on Reader Service Card

LUBRICANT FOR ELECTRICAL CONTACTS INTRODUCED

Electrolube, a new lubricant and conditioner for electrical contacts, has been introduced to the United States market by Electralab Printed Electronics Corp., a subsidiary of Farrington Manufacturing Company.

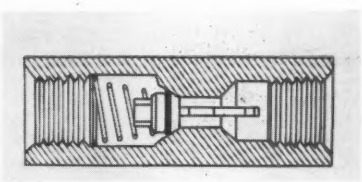
The manufacturer states that the lubricant increases the life of contact surfaces and conditions by reducing layers of tarnish. The high molecular weight, branch chain, saturated ester may be used on arcing as well as non-arcing contacts.

Electrolube, which has been used in England for the past six years, is said to be water-repellent and non-drying, and has the lowest electrical resistance of any non-aqueous lubricant, increasing brush life by 300 percent and has a wide temperature range—it pours at −50F, flashes at 457F.

Circle No. 9 on Reader Service Card

NEW CHECK VALVE MANUFACTURED

A new line of check valves designed to allow free fluid flow in one direction and to block reverse flow has been announced by the Manatrol Corporation, Cleveland, Ohio.



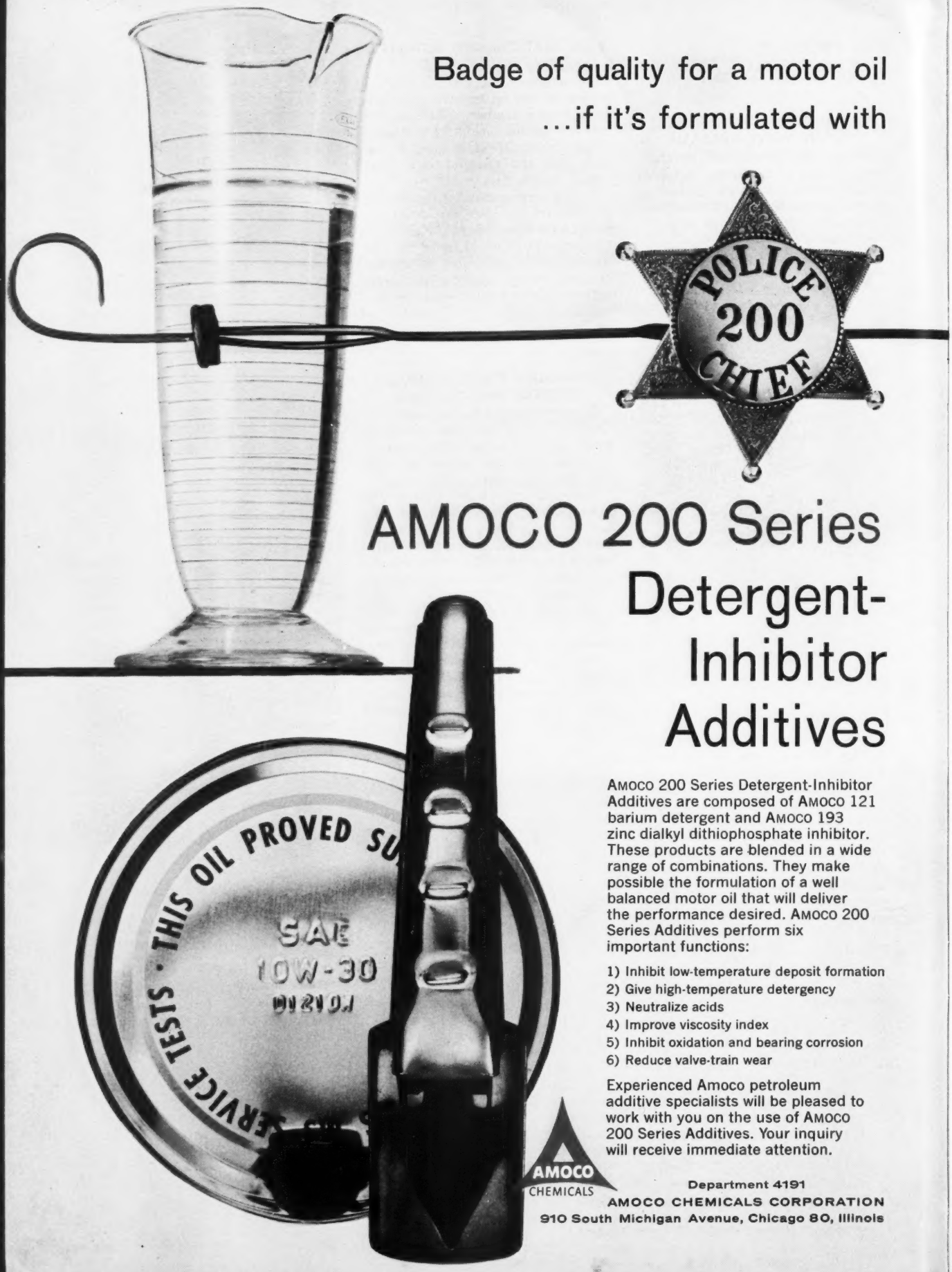
Featuring one-piece, leakproof bodies with a minimum of components, these valves are constructed with soft seats to assure positive sealing. The simplified design permits large flow passages and in-line construction to minimize pressure drop and prevent loss of power. The design also features a horizontal poppet guide for accurate seating, efficient checking and in-line self-cleaning action. Additional features are: a long life stainless steel spring; a single seal and a positive poppet stop that prevents over-compression of the spring.

Built for operating pressure ranges up to 5,000 psi, the valves are available in either brass, steel or stainless steel bodies with ⅛" through 1" dry seal threads or AND-10050 ports with straight threads. Units can be easily installed and will handle any fluids compatible with the material.

Circle No. 10 on Reader Service Card

(*Continued on page* 505)

Badge of quality for a motor oil
...if it's formulated with



AMOCO 200 Series Detergent-Inhibitor Additives

AMOCO 200 Series Detergent-Inhibitor Additives are composed of AMOCO 121 barium detergent and AMOCO 193 zinc dialkyl dithiophosphate inhibitor. These products are blended in a wide range of combinations. They make possible the formulation of a well balanced motor oil that will deliver the performance desired. AMOCO 200 Series Additives perform six important functions:

1) Inhibit low-temperature deposit formation
2) Give high-temperature detergency
3) Neutralize acids
4) Improve viscosity index
5) Inhibit oxidation and bearing corrosion
6) Reduce valve-train wear

Experienced Amoco petroleum additive specialists will be pleased to work with you on the use of AMOCO 200 Series Additives. Your inquiry will receive immediate attention.

AMOCO CHEMICALS

Department 4191
AMOCO CHEMICALS CORPORATION
910 South Michigan Avenue, Chicago 80, Illinois

NEW PRODUCTS

(*Continued from page* 503)

SELF-EMULSIFIABLE SPERM OIL

An entirely new product, self-emulsifiable sperm oil, has been developed by Werner G. Smith, Inc., of Cleveland, Ohio. Known as W-G-S Sperm Oil "42", the new product provides the desirable lubricating properties of sperm oil, plus easy emulsification by simply agitating with hot or cold water. Permanent emulsions are formed with as little as 5 to 10% W-G-S "42" and 90 to 95% water.

The new product is not water soluble and very low percentages of Sperm Oil "42" (such as 1%) will not form emulsions. The manufacturer states that because it is in an emulsion and not a solution, the sperm oil will coat metal and form an oil film which will not wash off with water.

Sperm Oil "42" contains a chemically-bound emulsifier and has low-viscosity and anti-rust properties. It is claimed to be stable in acid or alkaline solutions and soluble in petroleum solvents. It is non-toxic, has less odor than sperm oil, contains no sulfuric acid, sulfates, sulfonates, nor added non-ionic emulsifiers. An amber colored liquid at room temperature, W-G-S Sperm Oil "42" forms a creamy emulsion with water.

To provide extreme pressure properties, it can be reacted with chlorine or phosphorus. To make it water soluble, it can be sulfated or reacted with ethylene oxide or strong alkalis.

Circle No. 11 on Reader Service Card

"NO FLAME" GREASE COMPOUNDED

Called "No-Flame" Grease because it reportedly won't burn under any conditions, a new specialty that is claimed to be non-melting, maintaining its stability under all extremes of temperature and of pressure, is announced by the Bel-Ray Company.

The manufacturer claims that the white "No-Flame" Grease doesn't discolor under extremes of temperature or pressure; that it is non-carbonizing and non-corrosive.

A mailer containing a cellophane blister with a glob of "No-Flame" Grease in it and a packet of matches with the message, "Go ahead—try—'No-Flame' Grease won't burn," is available upon request.

Circle No. 12 on Reader Service Card

TEFLON DRY FILM LUBRICANT INTRODUCED

"Fluoro Glide", a new aerosol-applied multi-purpose dry film lubricant, has been introduced by Chemplast Inc. It is a colloidal form of teflon dispensed by a Freon propellant. According to the manufacturer, it lays down a smooth, quick-drying, almost frictionless film of Teflon—preventing galling, freezing or abrasion of adjacent surfaces.

Like solid Teflon, this lubricant is claimed to be non-greasy, does not drip or cake and provides a surface with the lowest coefficient of friction of any solid material. Since its static coefficient of friction equals its dynamic coefficient of friction, there is no stick-slip type of motion. It is completely inert to nearly all chemicals and can be used continuously at temperatures as high as 600°F or as low as the cryogenic range.

"Fluoro Glide" is recommended by the manufacturer for laboratory purposes such as the industrial and domestic lubrication of sliding parts of instruments; glass stopcocks, stoppers and tapered joints; reciprocating parts; threaded connections and assembly of glass and rubber tubing.

Circle No. 13 on Reader Service Card

NEW SYNTHETIC WAX DEVELOPED

A new high melting synthetic wax is now being manufactured commercially. It is a brown hard wax with a melting point of 156°C (313°F) and it has a very high flash point and good electrical insulating properties.

The wax is insoluble in all solvents at ordinary temperatures, and it is compatible with paraffin and microcystalline waxes, vegetable waxes, fats, esters, hydrogenated caster oil and rosin. Small amounts of this wax raise the melting points of the preceding considerably. Thus 10% added to paraffin wax raises the melting point to 142C.

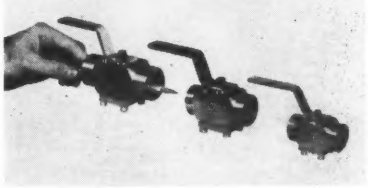
Because of these properties, this wax designated as ROSS WAX 160, is suggested for dielectric coatings and encapsulations; as a dry powder lubricant for drawing metal wire. In plastics it can serve as an integral lubricant and mold release. In paint and varnish it may increase moisture and salt-spray resistance. For paper coating, it aids water- and grease-proofing. In textile finishing, it aids waterproofing and fiber lubrication. Similar to Carnauba Wax, it has the property of releasing solvent from wax pastes.

Circle No. 14 on Reader Service Card

NEW TUFLINE INSTRUMENT VALVES FEATURE TEFLON SLEEVES

A new line of Tufline instrument plug valves featuring Teflon sleeves has been introduced by Continental Manufacturing Co.

Rated for 300# ASA service, the valves, which have screwed ends, are available in sizes ¼" through 1". They are recommended for on-off use on rated pressures within temperatures from −50°F to +400°F, with gas or liquid, corrosive or non-corrosive media.



The body bore construction is such that it provides an increase in the resilience of the specially processed pure Teflon sleeve. Leak-proof shut-off is assured even under conditions of fluctuating temperature. Design features of these new Tufline instrument valves include the use of an inverted tapered plug and bottom diaphragm cover seal so that line pressure actually reinforces the plug seal.

Because all moving parts in the valves are supported by low-friction Teflon, no lubrication is required, and product contamination, seizing or galling is eliminated.

Specification sheets and additional information on the new line of Tufline instrument plug valves may be obtained.

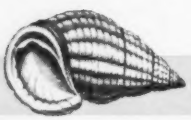
Circle No. 15 on Reader Service Card

Wherever in the world your industrial machinery operates...

Shell Alvania Grease is there

Other outstanding Shell Industrial Lubricants available world-wide

- **Shell Tellus Oils**—for hydraulic systems
- **Shell Talona R Oil 40**—anti-wear crankcase oil for diesel locomotives
- **Shell Rimula Oils**—for heavy-duty diesel engines
- **Shell Turbo Oils**—for utility, industrial and marine turbines
- **Shell Dromus Oils**—soluble cutting oils for high-production metalworking
- **Shell Macoma Oils**—for extreme pressure industrial gear lubrication
- **Shell Voluta Oils**—for high-speed quenching with maximum stability



AN INTERESTING FACT!
Every Shell Branded Industrial Lubricant is named for a sea shell. Shown here is the **Alvania** beanii.

Around the world, Shell Alvania Grease is available—under the same brand name and providing the same outstanding lubrication. This is assurance that your customers abroad will enjoy the same performance from your equipment that domestic customers rely upon.

Alvania® Grease offers these performance-proved advantages: (1) It provides safe lubrication at both high and low temperatures. (2) It won't wash out even in locations where water splashing can't be avoided. (3) It has built-in protection against rust and pitting of anti-friction bearings. And because this *one* multi-purpose grease is specially designed to satisfy as much as 90% of industrial grease needs, less servicing time is required; inventory costs are less; and there is less risk of misapplication.

No matter where your machinery is shipped, make Shell Alvania Grease your standard recommendation. Write for complete information.

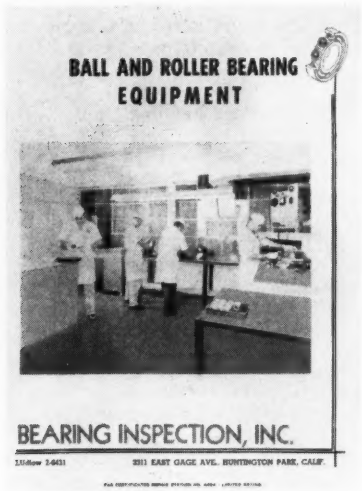
SHELL OIL COMPANY

50 WEST 50TH STREET.....NEW YORK 20, N. Y.
100 BUSH STREET.....SAN FRANCISCO 6, CALIFORNIA
IN CANADA: SHELL OIL COMPANY OF CANADA, LIMITED
505 UNIVERSITY AVENUE.....TORONTO 2, ONTARIO

PRODUCT LITERATURE

BROCHURE ON BALL AND ROLLER BEARING MAINTENANCE EQUIPMENT PUBLISHED

Cleaning and relubricating equipment for ball and roller bearings is the subject of a newly released 8 page illustrated brochure by Bearing Inspection, Inc., Huntington Park, Calif. The manufacturer claims that the equipment described will handle bearings ranging in size from ¼" to 14" OD, and it will clean most bearings with the shields in place.



Circle No. 16 on Reader Service Card

FOLDER ON RULON AND TEFLON PARTS NOW AVAILABLE

The 4-page Brochure No. 9572 describing the electrical, physical, mechanical, and chemical properties of RULON and TEFLON is now available from the Plastics Division of the Dixon Corp.

Especially helpful to design engineers, the brochure gives a comparison of the properties of RULON and TEFLON and shows typical applications of these materials in such industries as textile machinery, chemical and food processing, electronics, missiles, etc.

Circle No. 17 on Reader Service Card

BALL BEARING UNITS CATALOG AVAILABLE

Sealmaster Bearing Division, Stephens-Adamson Mfg. Co., has announced the availability of Catalog 454 presenting the complete line of high quality ball bearing units.

The literature features technical and engineering data, specifications, diagrams, illustrations and typical applications of the popular Sealmaster Line of ball bearings. The catalog points out the permanent seal, prelubrication, self-aligning and zone hardening features of its ball bearing units.

Circle No. 18 on Reader Service Card

FORMULAS FOR SOLUBLE CUTTING OILS RELEASED

Formulas for soluble cutting oil concentrates are described in a bulletin available from Atlas Powder Company.

Developed for a low-cost, stable product that forms emulsions readily at room temperature in waters of varying hardness, one formulation is based on a paraffinic oil and the other is based on a naphthenic oil.

Circle No. 19 on Reader Service Card

BULLETIN ON NEW SOLID FILM LUBRICANT PUBLISHED

The new SURF-KOTE A-1290 air drying solid film lubricant is described in a two-page bulletin.

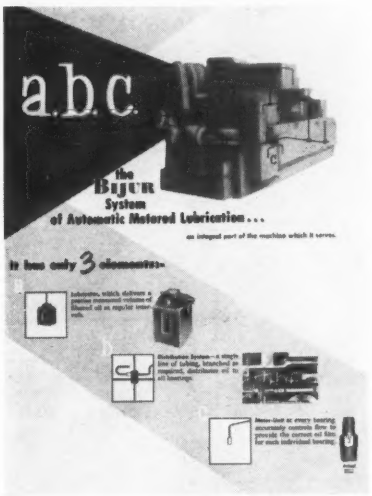
SURF-KOTE A-1290, containing a molybdenum disulfide compound, was developed by Hohman Plating and Manufacturing Company to provide a hard durable solid film lubricant on most types of metallic surfaces, preventing galling, seizing, fretting, corrosion, cold welding and similar friction problems over a wide range of pressures, temperatures and surface speeds.

Applied by spraying, dipping or brushing, SURF-KOTE A-1290 is developed to air-dry in 15 to 20 minutes, eliminating the need for high temperature curing. It is suggested for lubricating surfaces inaccessible after assembly and for field application on heavy machinery and parts too large for curing ovens.

Circle No. 20 on Reader Service Card

AUTOMATIC LUBRICATION BULLETIN PUBLISHED

A four-page, two-color bulletin entitled "The A.B.C. of Modern Lubrication" is being reissued by Bijur Lubricating Corp., Rochelle Park, N. J. The bulletin describes and illustrates the three basic elements of automatic lubrication—lubricators, distribution systems and "Meter Units."



Eight types of automatic lubricators are shown. Distribution system details—including information on the variety of tubing, junctions and flexible hoses—are given.

A third section describes the Meter-Unit which regulates the amount of oil flow at each bearing. Cut-away view shows the simple internal construction of the Meter-Unit filter, metering orifices and check valve. Bijur's offer to develop, without charge to machinery builders, complete designs for built-in central lubrication systems is included in the bulletin.

Circle No. 21 on Reader Service Card

BULLETIN DESCRIBES SYNCRO-RANGE-DRIVES

The Louis Allis Co. offers Bulletin 111, describing Syncro-Range-Drives, ranging in sizes 2 to 15 HP, and providing adjustable speed of synchronous induction motors running in exact synchronism over a wide range of speed.

Circle No. 22 on Reader Service Card

SOCIETY NEWS

NEW ASLE MEMBERS—AUGUST and SEPTEMBER, 1960

BOSTON

DONALD J. CHALEKI
Morgan Construction Co.
Worcester, Massachusetts

RICHARD E. FONTAINE
Morgan Construction Co.
Worcester, Massachusetts

WILLIAM R. NAYLOR (R)*
Sun Oil Company
Milton, Massachusetts

CHICAGO

DR. GEORGE J. ROTARIU
Booz-Allen Applied Res. Inc.
Glenview, Illinois

JOSEPH T. LUNDQUIST (R)*
Lundquist Lubricating Co.
Chicago, Illinois

CLEVELAND

HAROLD M. CONVERSE (R)*
Central Petroleum Co.
Cleveland, Ohio

CONSTANTINE F. BOWBLIS
Shell Oil Company
Cleveland, Ohio

DONALD M. CONROY
Acheson Colloids Co.
Cleveland, Ohio

DONALD L. THOMPSON
Cincinnati Vulcan Oil Co.
Cincinnati, Ohio

E. JAMES VARGO
Cleveland Graphite Bronze Co.
Cleveland, Ohio

CHARLES H. WEST
Timken Roller Bearing Co.
Canton, Ohio

LOS ANGELES

ARTHUR D. BRABBS
The Lubrizol Corp.
Pasadena, California

LOUIS H. COLE, JR.
Union Oil of California
Los Angeles, California

CINCINNATI

JOHN F. HOGAN III
Sun Oil Company
Cincinnati, Ohio

CENTRAL OHIO

FREDERIC K. ORCUTT
Battelle Memorial Institute
Columbus, Ohio

W. A. GLAESER
Battelle Memorial Institute
Columbus, Ohio

JAMES A. MOKAS
Sun Oil Company
Columbus, Ohio

DETROIT

CALVIN F. LONG
The Elco Lubricant Corp.
Detroit, Michigan

JOSEPH H. CARROLL (R)*
Sinclair Refining Co.
Detroit, Michigan

JOHN J. SCHRENK
Shell Oil Co.
Detroit, Michigan

JOHN W. SWAIN, JR. (R)*
Mergraf Oil Products Co., Inc.
Northville, Michigan

HOUSTON

J. P. PETREE
Shell Oil Company
Houston, Texas

KINGSPORT

PAUL E. WALKER (R)*
Esso Standard Oil Company
Knoxville, Tennessee

NEW YORK

NEWTON L. ABRAMSON
Borne Chemical Company, Inc.
Elizabeth, New Jersey

HAROLD McDONALD
Continental Oil Company
Englewood, New Jersey

BURT E. MYRICK (R)*
Delco Battery Operations
Princeton, New Jersey

PHILADELPHIA

ALLEN R. RICKLOFF
General Electric Co.
Erie, Pennsylvania

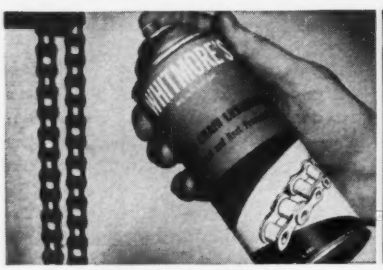
PITTSBURGH

WALTER E. YEDLINSKY
The Briggs Filtration Co.
Pittsburgh, Pennsylvania

JOHN A. BOHNA
Sun Oil Company
Pittsburgh, Pennsylvania

(*Continued on page* 509)

TRIAL SAMPLES
Of World-Famous WHITMORE'S Lubricants



OPEN CHAIN LUBRICANT INCREASES CHAIN LIFE UP TO 300%

Penetrates, lubricates, prevents rust. Lubricates deep into chain linkage to reduce friction on pins, rollers, bushings, pressure surfaces. Corrosion inhibitor prevents rust in vital working mechanisms. Lubricates close-tolerance internal surfaces to increase chain life up to 300%. Highly recommended for all climatic conditions to stop rust and corrosion even in salt atmospheres.

Packaged in handy 16 oz. aerosol spray-on containers or in bulk—send for a free trial sample.

ANTI-FRICTION COMPOSITIONS HAVE NO MELTING OR DROPPING POINT

Packaged in 14½ oz. cartridges for handy application with lever-type cartridge guns for constant protection to roller, ball, sleeve bearings and sliding surfaces in "hot" bearing applications or in areas with high ambient heat. Exclusive formulas have no melting or dropping point; moisture resistant; will not wash out; exceptional metal adherence properties; temperature reducing qualities; high extreme pressure values. Available in two grades. Whitmore's Anti-Friction Composition No. 1 (light density), recommended for high speed, high temperature applications. Anti-Friction Composition No. 2 (heavy density), for low-speed high-temperature applications or loosely-fitted bearings. Specify No. when requesting free trial sample.

68 YEARS OF LEADERSHIP LUBRICATING THE FOLLOWING:

- Open Gears, Dipper Sticks, Cams
- Open and Enclosed Chain
- Speed Reducers
- Enclosed Gear Cases
- Roller, Ball and Sleeve Bearings
- Wire Rope and Cable
- Hydraulic Units, Torque Converters

Est. 1893
THE WHITMORE MANUFACTURING CO.
LUBRICATING ENGINEERS
CLEVELAND 4, OHIO • VULCAN 3-7272

Circle No. 23 on Reader Service Card

SOCIETY NEWS

(*Continued from page* 508)

MILWAUKEE

PHILIP T. WILCZYNSKI
Cities Service Oil Co.
Milwaukee, Wisconsin

ROCHESTER

CARL H. SCHULTZ
Delco Appliance Division GMC
Rochester, New York

SAGINAW VALLEY

JOHN E. DALTON (R)*
D. A. Stuart Oil Company
Saginaw, Michigan

TORONTO

EDWARD C. BROWN
Imperial Oil Limited
Toronto, Ont., Canada

UNAFFILIATED

WILLIAM J. BOOTH
The City of Oklahoma City
Oklahoma City, Oklahoma

DOUGLAS A. MARKEY
R. T. Vanderbilt Company
Tulsa, Oklahoma

PAUL W. PERFECT
International Paper Company
Panama City, Florida

JOHN H. SHROYER, JR.
The Lubrizol Corporation
Tulsa, Oklahoma

JOHN P. GRAHAM
Phillips Petroleum Co.
Bartlesville, Oklahoma

H. P. PERKINS
Texaco Incorporated
Camp Hill, Pennsylvania

ROY L. WARING
Cato Oil & Grease Co.
Oklahoma City, Oklahoma

FOREIGN

FRANCIS A. MARTIN
Esso Standard Oil SA
Port of Spain, Trinidad, W.I.

M. JACQUES ROQUES
Compagne de Raffinaga
Shell Berne
Paris, France

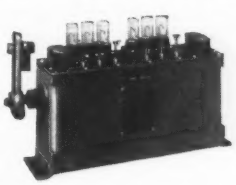
ENRIQUE GIMENEZ M.
Mexican Trading Company
S.A. Sun Oil Excel. Rep.
Mexico, D.F. Mexico

*Reinstatements

How to STRETCH

a drop of oil...

Manzel force-feed lubricators squeeze the full potential out of every drop of oil you purchase. Model "94", for example, pumps against pressures up to 3,000 pounds, handling any grade of oil from the lightest mineral oil to the heaviest cylinder stock with the same regularity. Model "94" starts, stops, speeds up and slows down in synchronization with your machinery. Every change in engine speed brings a corresponding change in the amount of oil delivered. For details on our whole line of *responsive, responsible* lubricators, write for our catalog. Manzel, 254 Babcock Street, Buffalo 10, New York. For the most efficient lubrication,



ask the man from

UNIT OF HOUDAILLE INDUSTRIES, INC.

Manzel

SPECIALISTS IN LUBRICATORS AND METERING PUMPS SINCE 1898

Better Greases Through BAROID RESEARCH

BARAGEL* gives more efficient gel structure —in a greater variety of oils

BARAGEL, a non-soap grease-gelling agent, gives high gel structure in a great variety of oils. This versatility is the result of constant research in Baroid Chemicals' Houston Laboratories. BARAGEL greases are compounded and subjected to the most rigid testing.

One of these tests measures oxygen absorption to determine the resistance of BARAGEL greases to oxidation. BARAGEL greases are easily inhibited with a variety of antioxidants to provide excellent oxidation resistance. Such greases show minimum oxygen absorption under the most rigorous operating conditions.

BARAGEL is a reaction product of mixed organic ammonium halides and refined sodium montmorillonite. BARAGEL is a member of the BENTONE* family of products which has been outstandingly successful in lubricating greases, paints, plastics, inks and other fields.

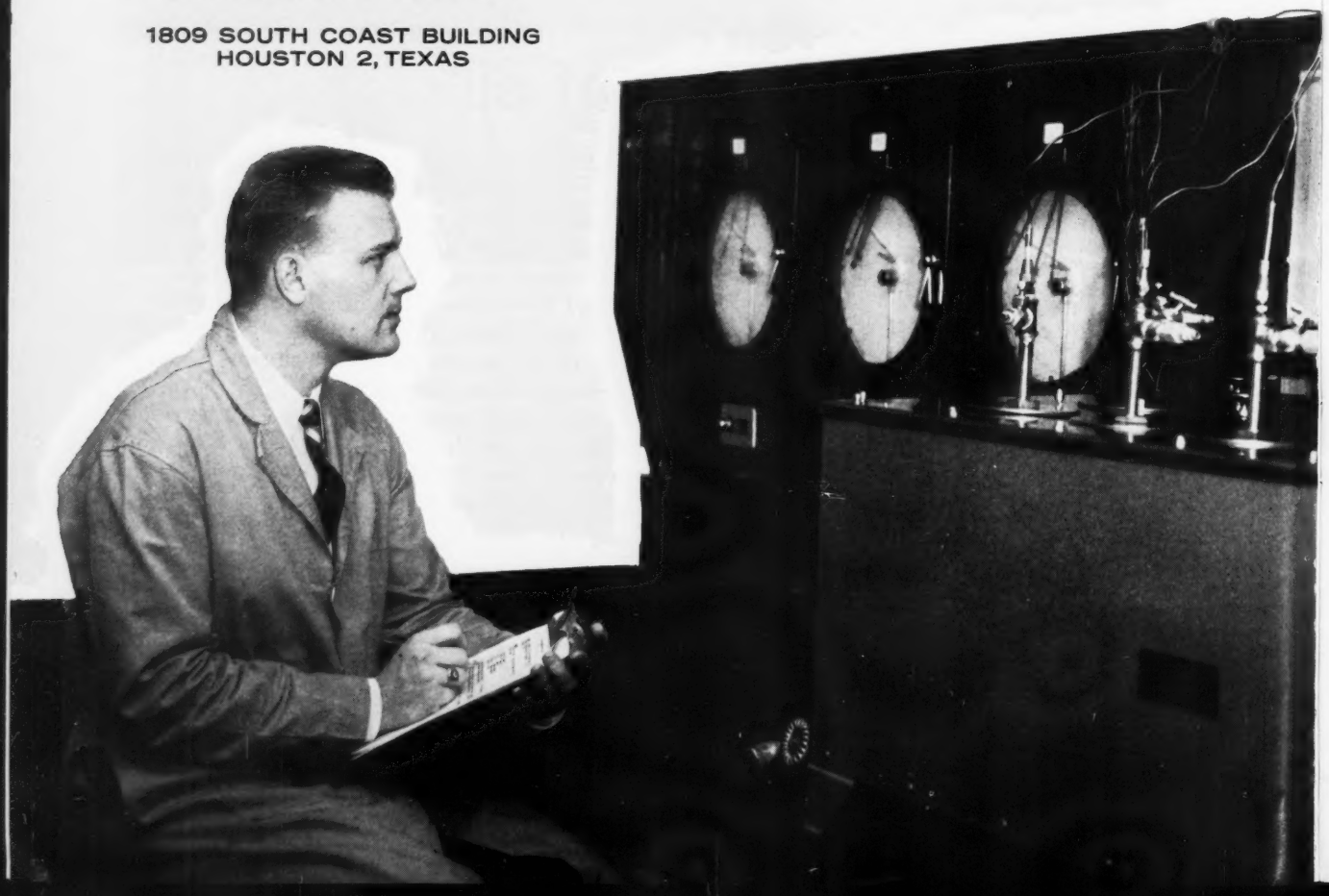
* Trademark of National Lead Company for an organic ammonium montmorillonite

6063

BAROID CHEMICALS, INC.

A SUBSIDIARY OF
NATIONAL LEAD COMPANY

1809 SOUTH COAST BUILDING
HOUSTON 2, TEXAS



SECTION NEWS

Boston—A one-day Educational Course will be sponsored by the Boston Section. The course is scheduled for March 21, 1961, and will coincide with the Section's regular March meeting. Describing Profitable Plant Lubrication, the course is planned to use the "5 R's of Lubrication" as the subject content: the Right Lubricant, the Right Place, the Right Amount, the Right Time, and the Right Price.

Other interesting programs which have been scheduled for the 1960-1961 season are:

Nov. 21—Full Fluid Lubrication
Jan. 16—ASLE President, L. O. Witzenburg
April 17—Polaroid Plant Visitation
May 15—Annual Past Chairmen's Night

New York—A six-week evening course in "Practical Lubrication Engineering" is currently being sponsored by the New York Section, which began October 4 and will run until November 15, 1960 in Newark, N. J. The following is a schedule of subjects and speakers included on the course program:

October 4—"Lubrication Fundamentals," R. G. Cunningham, Shell Oil Co.

October 11—"Properties of Lubricants," R. McKay and Stan Pier, Cities Service Research and Development Co.

October 18—"Hydraulics," K. G. Henrikson, Socony Mobil Oil Co.

October 25—"Metal Working," Arnold Ackerman, Anderson Oil Co.

November 1—"Bearings," T. A. Eddy, American Brake Shoe Co., and C. R. Gillette, New Departure Division, General Motors Corp.

November 15 — Panel Discussion, Panel Members: W. E. Sauerburn, U. S. Rubber Co., W. P. Rapp, National Biscuit Co., H. D. Lewis, Consolidated Edison Co.—Plant Lubrication; G. E. Kellis, Sinclair Refining Co.—Industrial Oil; Jack Zakin, Mobil Oil Co.—Industrial Grease; John Feltman, Sealol Inc.—Seals; L. E. Hoyer, American Brake Shoe Co. —Bearings.

Chicago — Students Night will be observed at the regular monthly meeting at the Builders Club, 228 North La Salle Street, at 6:30 p.m. on November 17. Dr. A. W. Sisko, Standard Oil Co., Whiting, Ind., will present a paper on "The Flow of Lubricants." Dr. Sisko will use visual aids with his talk.

Detroit—Chairman Wesley J. Wojtowicz announces that on November 29, 1960 the Detroit Section will sponsor a Symposium on "Diesel Engines" at the Detroit Diesel Engine Division, GMC, 13400 West Outer Drive, Detroit, Michigan. Registration for the session will take place at 9:00 a.m. Further information is available from the Symposium Chairman, J. A. Brady, P.O. Box 488, Detroit 4, Mich.

Rochester—On September 14, the Rochester Section held its first fall meeting when Mr. Nicholas Walton, formerly of England and now Special Products Sales Engineer, Special Products Division of Garlock, Inc., spoke on "Metal Baked Teflon Bearings for Operation in the Range of −328F to +536F." A large number of guests were in attendance in addition to the many maintenance and lubrication engineers present.

A one-day Lubricating Grease Symposium was held at the Manger Hotel on October 25 and sponsored by the Rochester Section. The symposium discussion included the past, present and future of greases and their use in industry and automotive type equipment.

Twin Cities—Mr. Carl Oldenburg, District Manager, Petroleum and Rubber Chemicals Division, Oronite Chemical Co., was the speaker at the September Twin Cities Section Meeting. Having been engaged in the research, manufacturing, and sale of lube oil additives for the past 15 years, Mr. Oldenburg is well qualified to speak on "Recent Developments in Motor Oil Additives."

Buffalo—The September meeting included an interesting tour of the Niagara Power Authority Project in Niagara Falls, N.Y. The tour was followed by a smorgasbord dinner.

Huntington-Charleston—The first regular monthly meeting of the 1960-61 season was held in Huntington at the Hotel Pritchard on September 15. The social hour and dinner was followed by the business session when Dr. W. H. Millett, Assistant Director, Technical Services Laboratory, Union Carbide Chemical Co., was featured. His talk "Industrial Uses of Synthetic Lubricants," was illustrated with slides.

Montreal—Featured at the regular October monthly meeting was Mr. G. W. Miller, President of Battenfeld Grease and Oil Corp., North Tonawanda, N. Y., whose subject was "A.B.C. of Grease Lubrication". The Montreal Section has announced plans to hold a "Lubrication Educational Course" in January, 1961.

Syracuse—The September 19 meeting featured Mr. Robert Gibbons, Chief Metallurgical Engineer, Bendix Corp., Utica, New York. Mr. Gibbons spoke on "Machinability Versus Micro Structure" and illustrated his talk with slides.

IN MEMORIAM

It is with deep regret that the many ASLE friends and associates of Mr. J. E. Buchanan learned of his death on September 10, 1960. Although he had been promoted to New York City as the Assistant Divisional Manager of Industrial Sales for Texaco, Inc., his interest remained very much with the Baltimore Section's activities. C. J. DeVries, Baltimore-Richmond-Philadelphia Area Representative, says of Mr. Buchanan, "Buck was a friend and advisor to all who knew him and did more to promote the Baltimore Section than anyone now connected with our organization."

MEMO TO ASLE TRANSACTIONS SUBSCRIBERS:

Subscriber response to ASLE Transactions for 1960 is overwhelming and the Officers and Directors of ASLE are indeed gratified by your support.

Unfortunately, ASLE has been unable to live up to its responsibility, mainly because of conditions beyond its control. We, however, expect to have both copies of Volume 3 in the mail to you by the end of the year.

Appropriate action has been taken to assure that in 1961 ASLE Transactions will be delivered to you on schedule.

REVIEW PROCEDURE CHARTS FOR ASLE PAPERS

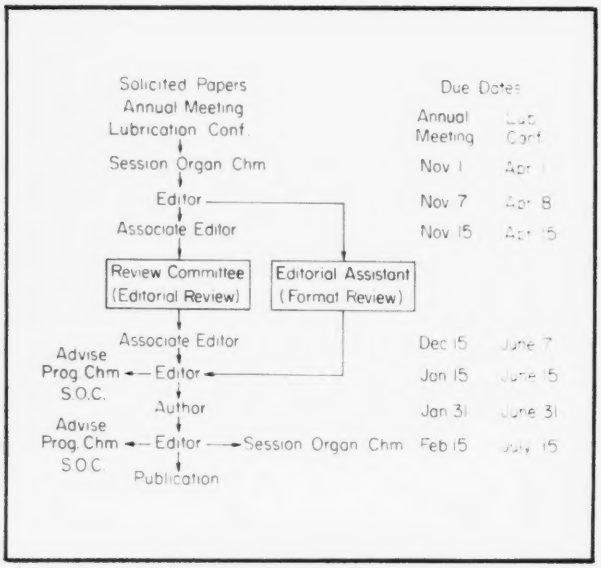


Chart 1 — Handling procedure for solicited papers for Annual Meeting and Lubrication Conference

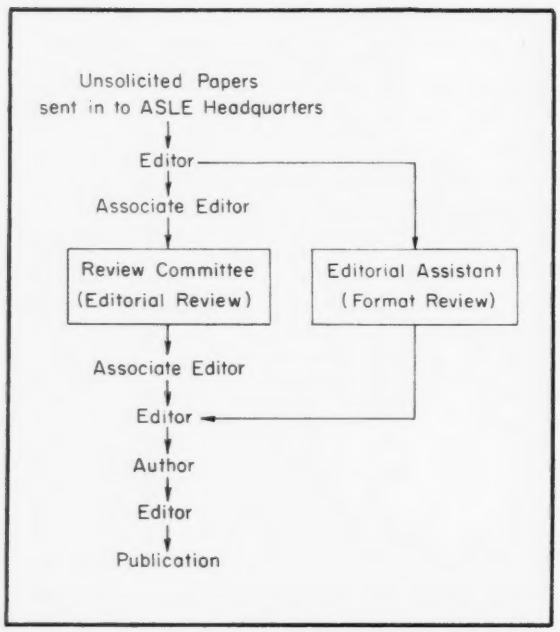


Chart 2 — Handling procedure for unsolicited papers sent in to ASLE Headquarters

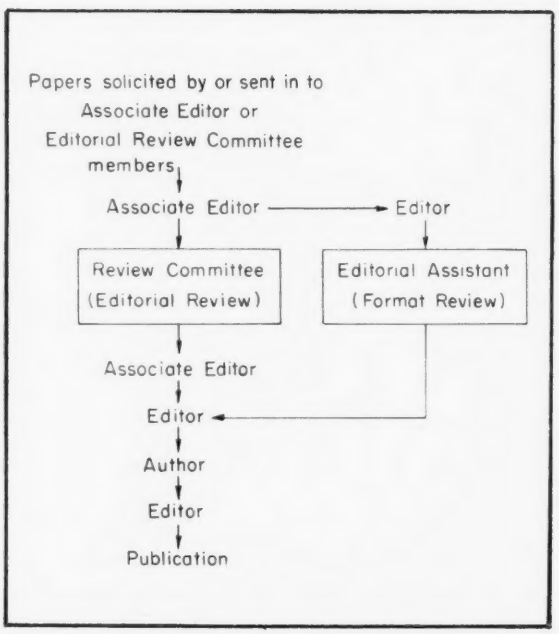


Chart 3 — Handling procedure for papers sent in to or solicited by associate editors or editorial review committee

Vol. 16, No. 11

Lubrication Engineering

the course of an ASLE paper

In order to expedite the review of papers both for presentation before Society meetings and for publication in Society publications, a unified review procedure is being set up for all Society papers. Under the new arrangement, a single review procedure will replace the two separate reviews, one for presentation and one for publication, which were formerly used. The change will make it possible to advise an author more quickly as to whether or not his paper can be published and will make it easier for him to meet publication requirements. At the same time, the new system will create a review organization which will not change annually as at present. The duties of this group will be to not only review submitted material, but to continuously be on the lookout for worthwhile papers in the field so that ASLE can give the best possible coverage of all phases of lubrication.

Under the new system, the general field of lubrication has been broken up into a number of smaller areas and an Associate Editor appointed to head a Review Committee composed of persons familiar with each particular area.

Each Associate Editor and his Review Committee (see page 512) will be responsible for seeing that the papers referred to them for review constitute worthwhile contribution to the lubrication literature and are of a quality consistent with the best interests of the Society. They will review each paper as to suitability for both presentation and publication. As previously mentioned, the Review Committees will not limit their activity to review only, but will keep abreast of important work in their particular fields and will solicit for publication, papers on important work which comes to their attention. This will in no way interfere with the solicitation of papers by Session Organizing Chairmen and others, as papers secured in this manner can be made available for presentation at Society meetings if the author desires.

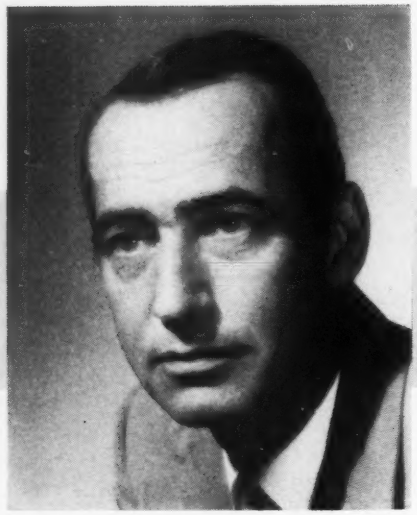
The new organization and the manner of handling the various types of papers which are received is shown in the charts on the facing page.

John Boyd
Editor

The Lubrication Engineer in Action

Officially, John Willcox is a mechanical engineer with a degree from the University of Pennsylvania in 1936. But his career has gone far afield. Since joining American Viscose as a staff engineer in 1937, his assignments have included phases of construction, design and operating.

This broad range of experience in the highly specialized field of rayon and cellophane manufacture led quite naturally to coverage of the lubrication engineering function when the need was recognized. Since then, Willcox has been the technical coordinator on lubrication problems in all of the company's seven plants. Whenever he can spare the time from a busy schedule, you'll find him wading a trout stream—except for the time it takes to run a mower over the six acres that surround his 100 year old home about a half hour outside of Philadelphia.



Report No. 5

JOHN K. WILLCOX
at American Viscose Corp.,
Marcus Hook, Pa.

Can any company enjoy the benefits and economies of lubrication engineering without a staff of specialists, without a lubrication laboratory or testing facilities, without even having a full-time lubrication engineer on duty? Briefly, this is the situation at American Viscose, and the following account of how John Willcox keeps familiar with the company's lubrication problems will shed some light on the question.

Before getting into the story, however, a broader look at lubrication engineering itself is in order. It will help explain Willcox's operation.

In the overall picture, there are three basic aspects of lubrication engineering. First is awareness of the importance of lubrication and the need for special attention to lubrication problems. This awareness is absolutely essential. Without it, lubrication engineering would never have emerged from its place as a minor phase of mechanical engineering and the tremendous progress that has been made in the past decade would never have come to pass.

Next there is the continually expanding body of knowledge, equipment and materials that makes it possible to practice lubrication engineering efficiently. This accumulation of technical information and facilities is the result of a team effort that embraces important contributions from many sources.

Lubricant producers and processors, equipment manufacturers, independent research organizations, leading universities and practicing lubrication engineers are all constantly at work testing and developing new materials and techniques of application. Special literature devoted to the subject, like this journal, helps make this information available to all. Free technical interchange, through personal contact or organized on a society basis, rounds out the dissemination process. Taking advantage of "the body of knowledge" and keeping up to date is essential in practical lubrication engineering.

The third and final aspect of lubrication engineering is application of available knowledge to the solution of problems in specific operating situations. This is accomplished in a number of ways, as has been shown in this series of reports, and the particular approach used is ordinarily one developed over a period of years to provide maximum efficiency under the existing conditions.

At American Viscose, management is aware of the need for lubrication engineering and has been for many years, as evidenced by the company's action in this area. Further, the company draws heavily on the "body of knowledge" existing in the lubrication field, perhaps to an even greater extent than do other organizations where complete laboratory set-ups and technical staffs are maintained.

It is only in the area of applying lubrication engineering to the local situation that American Viscose differs from the operations previously discussed in this series. And the reason that it has not been found necessary as yet to establish special facilities or a specialized technical staff are fairly obvious.

Fundamentally, American Viscose is engaged in chemical and material processing. Rayon fiber and cellophane are the company's principal products. Consequently, the lubrication problem is less complex and less critical than in a steel mill or a metalworking plant. By and large, fewer different applications are encountered and smaller quantities of lubricating materials are required in proportion to total output. Cutting fluids and coolants, for instance, are an important concern of lubrication engineering in a metalworking plant but are not used extensively in connection with production at American Viscose.

Yet, in an operation including 7 major manufacturing installations and more than 14,000 employees, even simple lubrication requirements can lead to a great deal of confusion, waste and production problems if not subjected to control of some sort.

Accordingly, lubrication engineering was made a specific concern of the central engineering staff on a company wide basis. At that time, assigned the project of coordinating and improving lubrication practices, John Willcox became the company's first lubrication engineer.

The set-up established then has persisted to this day. The central engineering staff consists of 3 groups —chemical processes, ultilities and services, machines and structures—reporting to the Director of Central Engineering. John Willcox, as a special assignment engineer, works with all of these groups and reports also to the Director.

Lubrication engineering is just one of the assignments with which Willcox is concerned and occupies only about 10 percent of his time now the operation is running smoothly. Previously, it took a much larger percent of his time for this coordination function.

As a matter of fact, the assignment itself, as lubrication engineer, is informal. Although superficial inquiry in connection with lubrication would lead to Willcox, lubrication engineering does not appear on the organization chart of the central engineering department nor in the formal description of Willcox's function.

Lubricating material procurement, similarly, is centralized. All oils, greases and hydraulic media are purchased by one buyer in the central purchasing section on a brand name basis in accordance with requisitions which originate at the plant level.

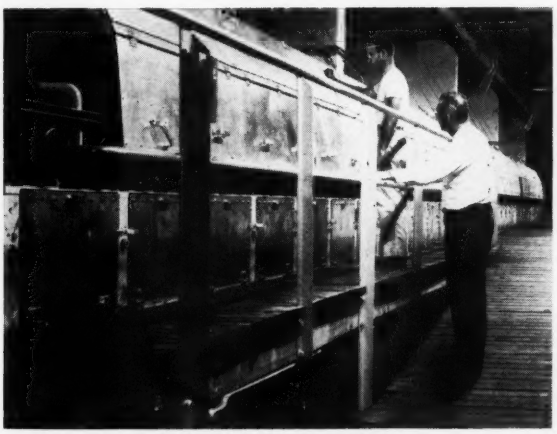
Yet, by close cooperation of plant personnel, purchasing department, and the continuous technical help of suppliers, a much higher degree of standardization of lubricants has been achieved. The number of different branded items in use has decreased by approximately half despite diversification and expansion of the company's manufacturing activities.

Other accomplishments under this system include:

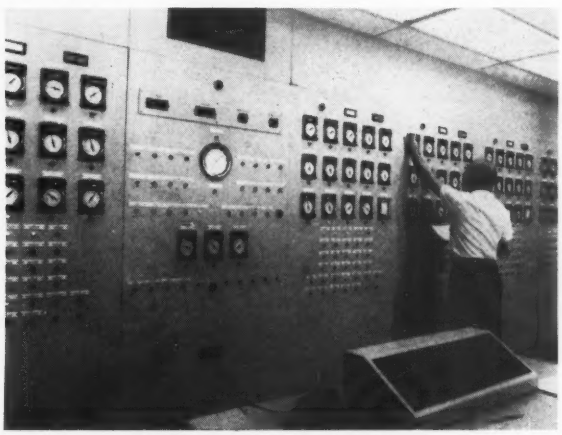
1. Establishment of definite lubrication schedules and procedures.
2. Institution of a lubrication training program.
3. Salvage and reconditioning of lubricants formerly discarded.
4. Emphasis on lubrication in equipment design.

A great deal of the equipment used in the production of rayon and cellophane is, of course, of special design. Preparation of detailed lubrication instruction charts is an integral part of the equipment design process.

The charts are released by the design group of central engineering together with each piece of new

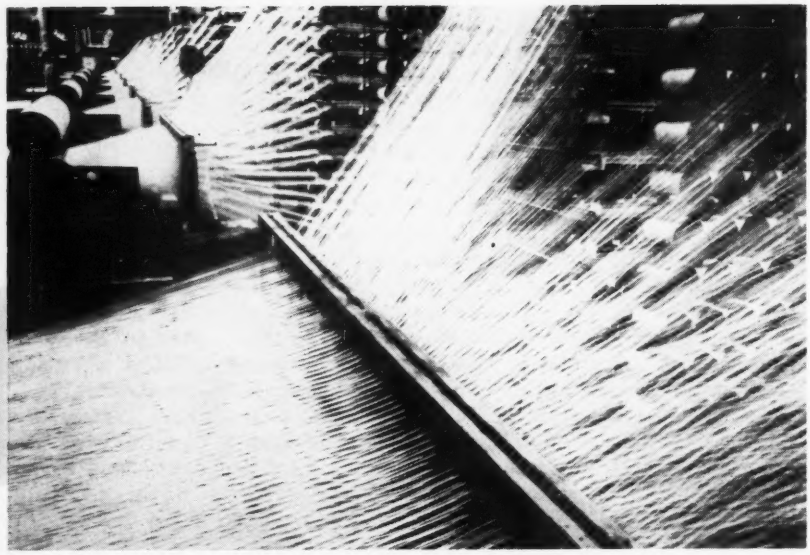


Cellophane Processing Machine.



Instrument and Control Panel for Cellophane Casting Machines.

Cones for Rayon yarn on creel feedings slasher for further processings prior to shipment.



Creels for Rayon yarn.

equipment and go to the plant engineering staff at the production location. Plant engineering then prepares actual working lubrication schedules from these charts.

These schedules, in turn, guide the activities of the oiler crews at each plant—and provide the suppliers with an invaluable means for maintaining and improving the efficiency and consistency of lubrication practices throughout all the American Viscose plants.

With actual lubrication carried out in accordance with written procedure, performance can be checked against the schedules and schedules themselves are always subject to review and modernization. In essence, the lubrication charts and schedules are the only written record of lubrication practices and as such are the backbone of lubrication engineering.

The training program, aimed at both the oiler crews and the plant engineering staffs, has been initiated and is a continuous never ending program. The objectives are to increase appreciation for the importance of proper lubrication and at the same time to upgrade the general level of lubrication technology.

At this stage, actual training consists primarily of informally scheduled seminars led by field engineers from the service staffs of various suppliers of lubricants and lubricating equipment. Attendance at showings of special technical films is also encouraged and case study or application information is circulated in memo form.

While it is too early to evaluate the success of this program, or even to compare the effectiveness of various approaches, gains have been made in helping to solve a fundamental and very common problem.

Strangely enough, this problem has nothing to do with misapplied lubricants or neglect. Rather, it is the result of misguided enthusiasm—over lubrication. With thousands of small electric motors in use throughout the American viscose organization, failure due to lack of lubrication is virtually unknown whereas failure due to "choking" with grease is altogether too common.

How has all of this been accomplished in what might seem to be casual fashion, especially by comparison with more elaborate lubrication engineering operations? The fact remains that John Willcox spends only a fraction of his time wearing the lubrication engineer's hat.

Two factors have been primarily responsible for the progress made. The first is time—continuous effort. What has been accomplished has been accomplished gradually and without the pressure of critical necessity. Procedures and schedules as they now exist are the result of constant awareness of opportunities for improvement. The methods used have been based on just plain good engineering—careful investigation of specific problems and plenty of testing.

Trial applications of new lubricating materials and equipment that show promise, under careful engineering control, are in process all the time.

A typical problem that led to improvement involved accelerated wear on slasher drum bearings where excessive moisture in the form of steam made lubrication difficult. The approach and eventual solution followed a fairly typical pattern too.

Two methods offered possible remedy for the situation, a recirculating system with moisture scavenging provisions or a moisture resistant material. In logical sequence, the less costly of the two possibilities was tested first.

Then, when results with "moisture proof" lubricants were less than ultimately desired, the recirculating system was installed and functioned with complete satisfaction.

In another case of frequent bearing failure, this time in connection with cellophane processing, repeated tests of different lubricants failed to improve the condition. As the problem grew more and more serious, investigation went deeper and the final answer involved seals rather than the lubricant. An improved sealing system kept the lubricant where it belonged and solved the problem.

Unfortunately, not all problems yield so readily. One case in point is the need for frequent and costly reworking of vacuum pump valves that "cake up" as lubricants break down in the presence of the existing atmosphere.

Many different materials have been tested for this application and progress has been made. Service life between overhauls has been extended from 2 weeks to between 4 and 6 weeks but there is still a long way to go and tests are continuing.

However, problem by problem and solution by solution, of this kind of approach has added up to solid progress in lubrication engineering at American Viscose.

The other primary factor in this progress has been close cooperation with the suppliers of the lubricant materials used by the company. Indeed, it is this cooperation that has given Willcox the special laboratory and technical backing that are inescapably essential in lubrication engineering.

Thus, without time consuming involvement in specific and routine plant activities, lubrication practices and methods can be coordinated on a company wide basis. Where special laboratory testing is required, the lab work is done by the suppliers. But the reports and decisions to act are reviewed by Willcox in all cases.

An outstanding example of how this sort of cooperation with suppliers can lead to important gains in lubrication efficiency is an instance where six different greases were replaced with one. The multi-purpose grease was a new development by the supplier of

Cellophane Master Mill Rolls being wound on take-up equipment.

Cellophane Slitters cutting the film to customer specifications.

the six greases previously used and was tested at their suggestion. Gains in handling, storage and application economy were significant.

Incidentally, in the matter of storage and handling of lubricants, supplier cooperation is extremely important. Careful study of supplier stock locations and arrangement of delivery schedules has virtually eliminated storage and handling problems at American Viscose.

At this point, however, lest lubrication engineering be made to seem too easy, it must be re-emphasized that what Willcox has done at American Viscose has taken many years.

THE ASSIGNMENT

Sans title, sans notation on the company organization chart and sans official description, the lubrication engineering assignment at American Viscose is still about as challenging as an assignment can get. It stems directly from management awareness of the need for centralized attention to and control of lubrication practices and, in very simple terms, is a directive to "cover all angles."

To John Willcox, as a special assignment engineer, this is just one assignment among many. But it varies from most in that lubrication engineering is a continuing responsibility, a project that has no end. Each day brings new opportunities for improvement, new requiments to be met and new problems to solve.

Underneath it all, the basic motive behind management concern, is the drive for cost reduction. To decrease plant operating costs through improved lubrication technology and at the same time assure efficient handling of lubrication problems as they arise, is the real lubrication engineering assignment at American Viscose.

THE APPROACH

To meet this challenge, Willcox acts primarily as a coordinator. Within the company, he arranges and supervises tests and consistent company-wide application of what proves good. Outside of company circles, to take advantage of all that the rapidly developing science of lubrication engineering has to offer, he works closely with suppliers, research organizations and technical groups, and fellow members of ASLE.

Through periodic review of current activities, through periodic meetings with engineers of suppliers, through special investigation of unusual problems that can not be solved at the plant level, and through willingness to test and change when improvement seems possible, Willcox has made lubrication engineering a significant factor in American Viscose technical management.

THE RESULTS

Considering lubrication engineering on the basis of relative importance in the overall operating picture, the current situation at American Viscose indicates that the company's needs have been well taken care of. Results achieved over the years by means of patient and continuous application of sound engineering principles compare quite favorably with the results achieved in other situations where the critical nature of lubrication has necessitated a more highly specialized lubrication engineering set-up.

1. A higher degree of company wide standardization exists. Fewer different materials are required.
2. Understanding and appreciation of good lubrication practices has been increased.
3. Maintenance costs have been substantially reduced as a direct result of improved lubrication.

In the final analysis, the real lesson to be learned from what Willcox is doing at American Viscose is that good lubrication engineering does not follow a fixed pattern of procedure or depend on certain specialized facilities in all cases. Rather, it is based on continual awareness of the benefits that can be derived from improved lubrication practices and consistent effort to apply the most efficient possible materials and equipment in each specific set of circumstances.

A Survey of Lubrication Methods

Part 3— Compendium of Lubricating Devices

(continued)

This is the fourth article in this part

by Allen F. Brewer,*
Consulting Editor

Illustrated by Robert R. Wayne
Pittsburgh, Pa.

In the present, as in the last three parts, the main features of typical lubricating devices will be discussed. Again, the illustrations have been kept schematic to stress the principle of operation rather than the details of construction.

CENTRALIZED SYSTEMS

A centralized system provides a combination of timed and measured lubrication employing either oil or grease. "Centralized" refers to the fact that a number of lubrication points can be serviced from one place by operation of a suitable pumping arrangement. Centralized systems run the gamut from a hand operated pump lubricating a few points on a single machine, to a completely automated system serving a whole mill or factory. When properly applied, centralized systems can result in appreciable savings in direct and indirect maintenance costs, increased safety to personal and better housekeeping.

Basically, a centralized system consists of a pump or other means to pressurize the lubricant and lines through which the lubricant may be transmitted to the bearings or friction points. In some systems, often termed "direct," the stroke of the pump meters the quantity of lubricant the bearing receives and there are no metering valves in the line connecting the pump and bearings. In other systems, sometimes termed "indirect," a pump pressurizes the lubricant, but metering valves in the transmission lines are responsible for dispensing the proper quantity of lubricant to the bearings. The indirect system is more commonly used in this country, while the direct system is often employed in Europe.

Direct Systems

Figure 23 shows schematically the principle of operating of a direct system. The main moving part is a piston which may be actuated by a cam, as shown, or by some other suitable linkage either mechanically or manually powered. The piston has a hollow center that connects to a number of pockets on the piston surface. As the piston moves up into the close fitting chamber, as shown in Fig. 23B, pressure builds up in the lubricant causing the check valve in the end of the piston to open thus permitting the lubricant to flow down the center of the piston. During the upward travel of the piston, one of the pockets in the piston lines up first with the port on the left side of the pump body permitting lubricant to flow from the center of the piston out to a bearing. As the piston continues upward, (Fig. 23C) the left hand port becomes covered and the right hand port is connected to a pocket in the piston, thus permitting lubricant to flow to the right hand bearing. As the piston moves downward, the check valve closes and lubricant flows from the main reservoir into the pressurizing chamber as shown in Fig. 23A, thereby readying the device for the next lubricating stroke. Such pumps can be designed to lubricate up to a dozen or more friction points on each stroke.

Indirect Systems

There are four basic types of indirect systems in common use that differ from one another by the type of metering valve required or by the configuration of the lubricant transmission lines.

Single Line, Spring Return System:

Figure 24 illustrates schematically the first type of indirect system to be discussed—the single line system employing spring return metering valves. The pump supplies lubricant under pressure through the three-way valve to a number of metering valves connected to the common supply line. With the three-way valve in the position shown, the supply line is pressurized and the metering valves are actuated. When all the

*Consultant and author "Basic Lubrication Practice."

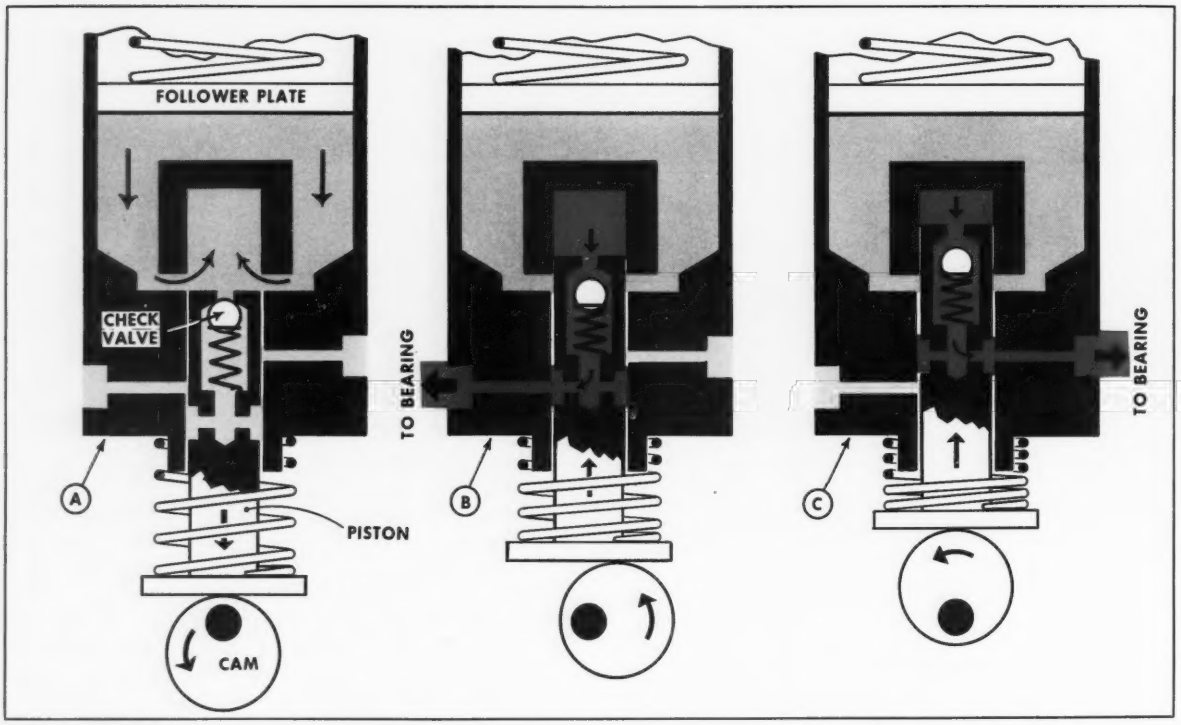


Fig. 23. Direct System.

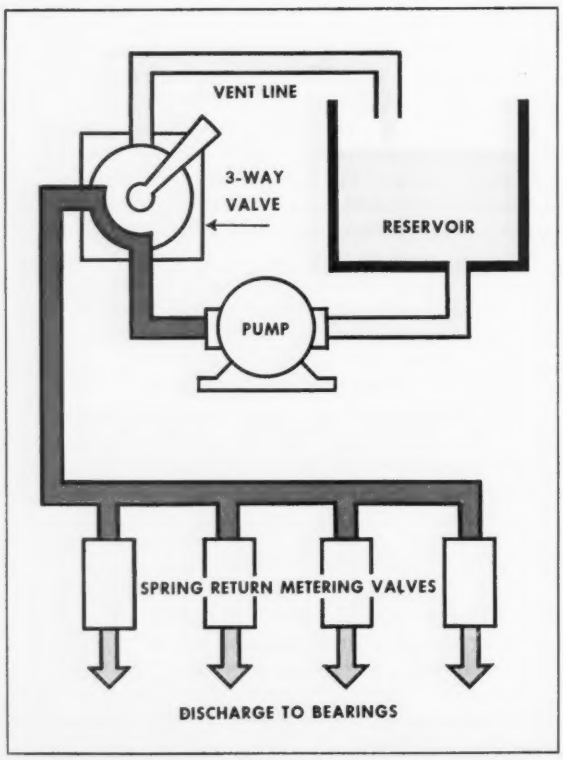


Fig. 24. Single Line System Employing Spring Return Valves.

valves have discharged, the handle on the three-way valve is turned 90° to recycle the system by venting the supply line thereby exhausting the pressure in the system. When the pressure in the supply line exhausts to a low enough value, compression springs reset the metering valves. Figure 25 is a cutaway schematic of a typical valve. In Fig. 25A pressurized lubricant from the supply line enters the valve and causes the piston to move down while at the same time filling the valve cavity with lubricant. In Fig. 25B a metered volume of lubricant is beginning to be dispensed. In Fig. 25C the meter piston has reached the end of its travel and the supply line has been vented. In Fig. 25D the pressure in the supply line has exhausted to the point that permits the compression spring to recycle the value.

Two Line Systems:

Figure 26 illustrates a second type of indirect system, the two line arrangement. The system consists of a reservoir and pump that supplies a four-way or reversing valve. Two supply lines run from the four-way valve, and the metering valves are attached as shown. With the handle of the four-way valve in the position shown, line (A) is pressurized causing the metering valves to discharge. During this period, line (B) is vented. When the four-way valve handle is turned 90°, line (B) is pressurized and line (A) is vented. This again causes the metering valves to discharge and to be returned to their initial condition.

Figure 27 shows the operation of one type of valve that may be used with the two line system described. In Fig. 27A, pressurized lubricant enters the metering valve from the supply line on the left, the supply line at the right being vented. The incoming lubricant moves the slide valve to the right. With the slide valve all the way to the right, as shown in Fig. 27B, the pres-

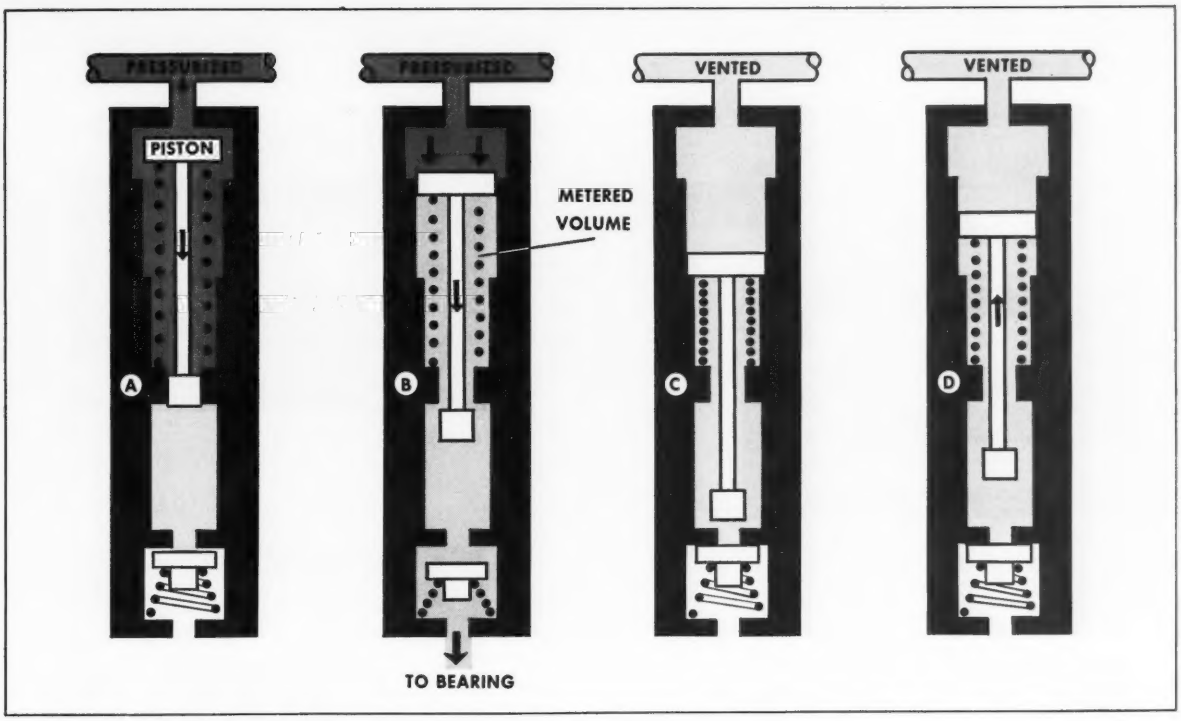


Fig. 25. Operation of a Spring Return Metering Valve.

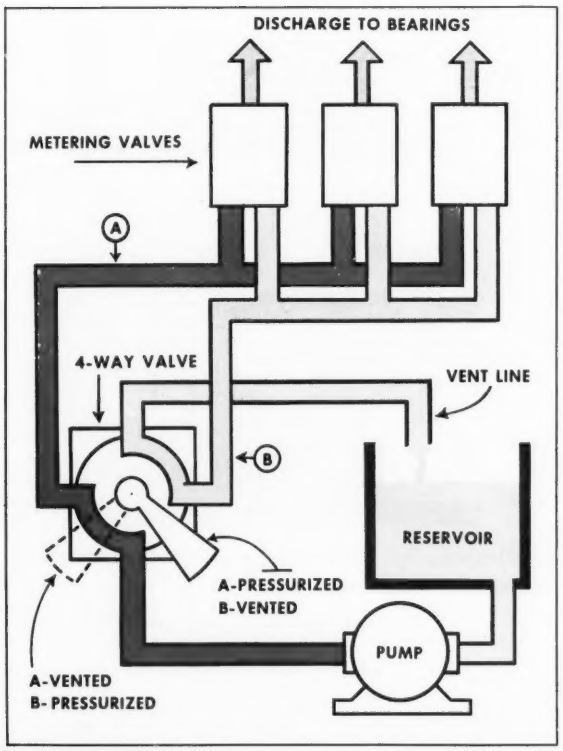


Fig. 26. Two Line System.

surized lubricant moves the metering piston to the left and a metered amount of lubricant is discharged to the bearing. When the metering piston completes its travel, as shown by the indicator, the handle of the four-way valve shown in Fig. 26 is turned 90° and the right hand supply line is pressurized and the left side vented as shown in Fig. 27C. The incoming lubricant moves the slide valve to the left. When the slide valve has been moved all the way to the left the pressurized lubricant drives the metering piston to the left, again dispensing a measuring quantity of lubricant to the bearing as shown in Fig. 27D.

Figure 28 shows the operation of another type of valve that may be used with a two-line system. In Fig. 28A pressurized lubricant enters the metering valve from the supply line on the left, the supply line on the right being vented. The incoming lubricant pushes up the left-hand flexible valve thereby closing bearing port 1. After the bearing port is closed, the supply pressure causes the flexible valve to deform as shown in Fig. 28B, permitting the lubricant to move the metering piston to the right. The lubricant ahead of the metering piston forces the right flexible valve to move downward, thereby opening bearing port 2 and permitting a metered amount of lubricant to be dispensed. When the piston reaches the end of its travel, the four-way valve shown in Fig. 27 is thrown, thereby venting the left supply line and pressuring the right supply line as shown in Fig. 28C. It should be noted that the flexible valve on the vented side has returned to its undeformed condition. As the pressurized lubricant flows in the right supply line, the right-hand flexible valve is pushed up and deformed thereby closing bearing port 2 and permitting the metering piston to move to the left. As the metering piston moves, the left-hand flexible valve is forced downward thereby opening bearing port 1 and permitting lubricant to be dispensed.

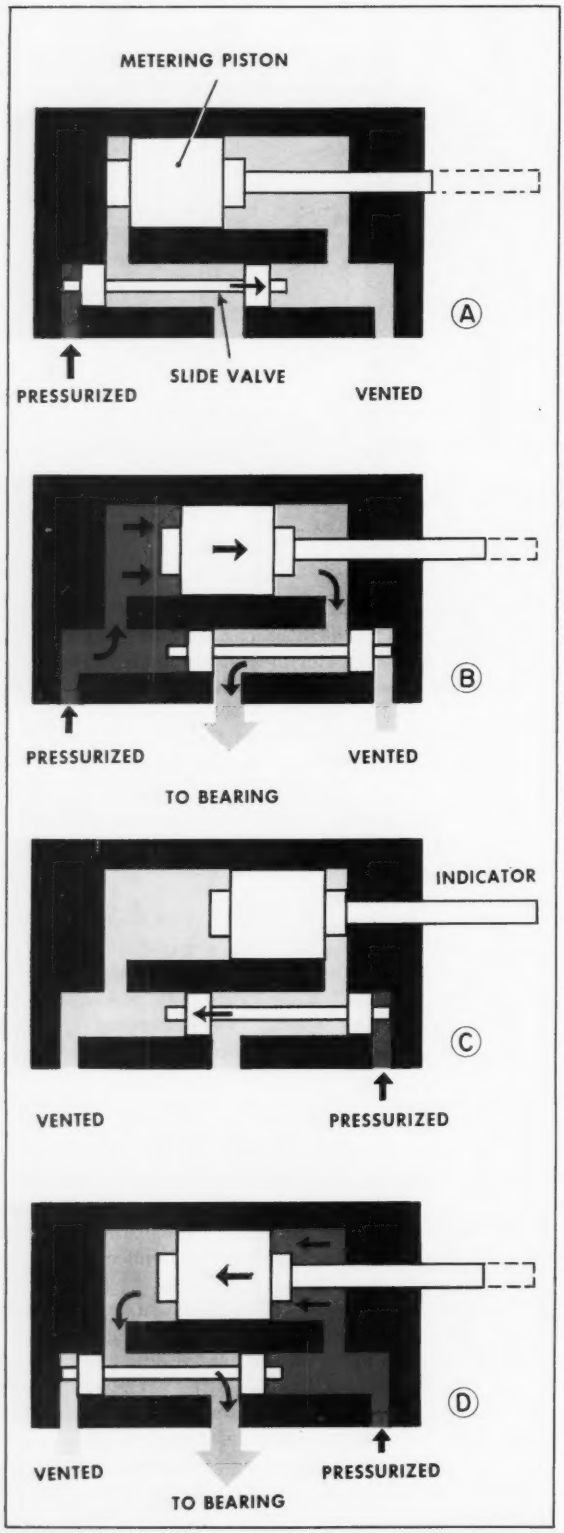


Fig. 27. Operation of a Valve for Use with a Two Line System.

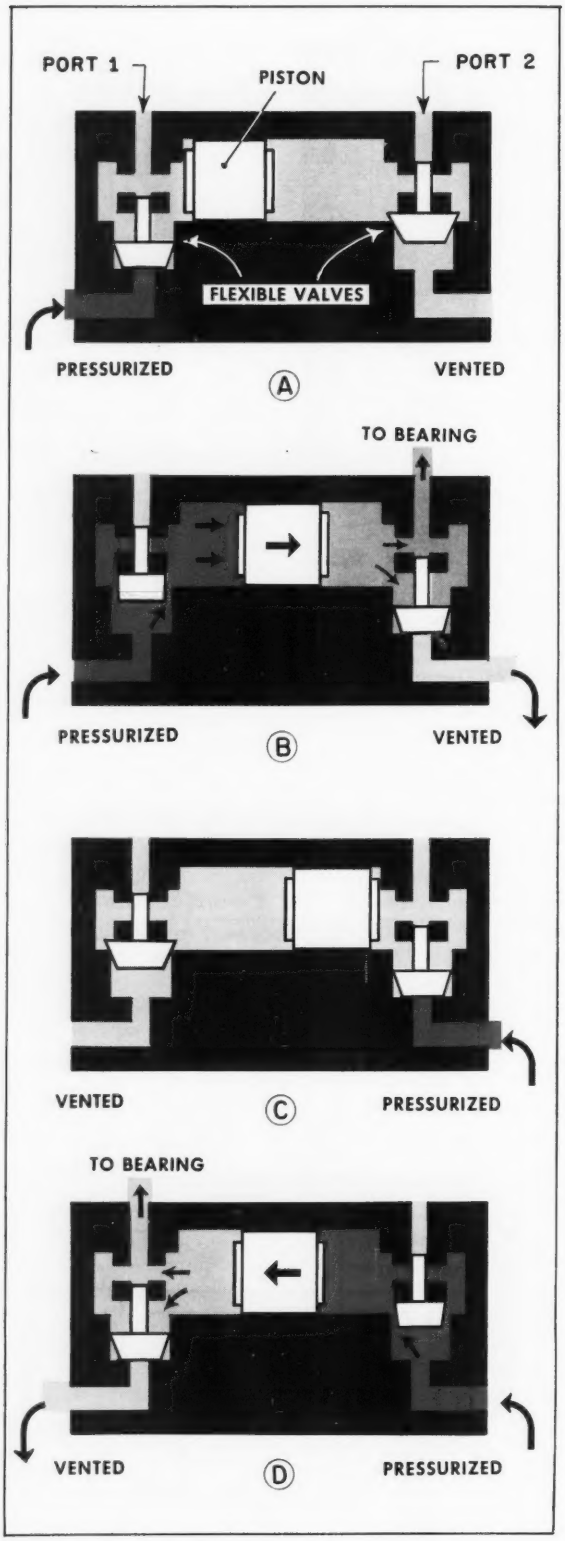


Fig. 28. Operation of a Valve for Use with a Two Line System.

(To be continued)

Relaxation Phenomena In Lubrication

by E. O. Forster
Products Research Division
Esso Research and Engineering Co.,
Linden, New Jersey

Lubricants, like all other materials, possess both elastic and viscous properties. The degree to which these properties manifest themselves depends on the molecular complexity of the lubricant, the stress range over which it is tested and the time scale on which the observations are made. Simple hydrocarbons of low viscosity exhibit elastic properties only in time intervals of about 10^{-12} to 10^{-9} seconds. The introduction of high molecular weight polymers would lengthen this time interval to 10^{-6} to 10^{-4} seconds. Semisolid lubricants, such as greases, appear to behave elastically, even in time intervals of 0.1 second or longer.

The significance of these elastic properties can be readily appreciated if one compares the above mentioned time intervals with loading times in actual dynamically-loaded machine elements. Calculations indicate that these loading times range from about 10^{-2} to 10^{-6} seconds when going from piston rings to ball bearings in turbo-jet engines. If the times during which the lubricant is subjected to rapid stressing is of the same order of magnitude as the relaxation time, the time in which the elastic properties become apparent, then the lubricant will behave elastically rather than viscously. Under these conditions, the lubricant will be present as an elastic film which can carry heavier loads than a viscous film and at the same time can prevent contact between the bearing surfaces and thus reduce or eliminate wear.

INTRODUCTION

The flow behavior of a lubricant is an extremely important factor influencing its lubricating ability. Flow characteristics have been adequately evaluated for most applications by conventional viscosity determinations in such instruments as the Ostwald or Ubbelohde capillary viscometer. These conventional viscosity determinations are based on the application of Newton's law, which assumes that the ratio of the applied force (the shear stress) to the flow rate (the shear rate) is a constant regardless of the levels of shear stress and shear rates.

The first and most obvious deviation from this law in the field of lubricants is the flow behavior of a grease. In fact, the utility of grease depends upon deviation from Newton's law. Polymer-modified oils exhibit behavior similar to greases, but only to a small degree, and the recognition of the dependency of their viscosity upon the level of shear rate has extended our knowledge of the behavior of such oils in actual equipment.

More recently, theoretical studies have suggested that at high pressures even straight mineral oils containing no soap or polymer deviate from Newton's law. This effect is in addition to the well-known increase in viscosity observed at high pressure. Unfortunately, the existing observations and measurements of pressure-viscosity effects are of limited value in ascertaining deviation from Newton's law because they do not extend to high enough shear rates (1) (2).

Conventional viscosity measurements are further limited by another assumption in Newton's law—namely, that lubricants respond to a stress by starting to flow instantaneously. The determinations in conventional viscometers are based on equilibrium flow rates under fixed stresses representing a steady state condition, which does not take into consideration any time dependence of flow. In actual service, lubricants gener-

Presented at the 15th ASLE Annual Meeting, Cincinnati, Ohio, April, 1960

ally are required to operate under dynamic, cyclic stresses, rather than steady state conditions. Under cyclic conditions, the lubricant could conceivably respond to stresses not only by viscous flow but also by elastic deformation. In fact, Maxwell (3) in 1867 predicted that if a liquid were stressed rapidly enough, it would show an elastic response. In other words, it would take a liquid a finite amount of time before it would exhibit viscous flow. The characteristic time that is required for the onset of flow is called the relaxation time and the transition from elastic to viscous response is referred to as a relaxation phenomenon. In the present paper, the time dependence of these elastic and viscous responses are discussed on the basis of our own experimental data and results published in the literature. Their practical significant in the lubrication of gears or bearings is also suggested.

ORIGIN OF VISCOELASTIC PROPERTIES

When a material is deformed, the molecules making up the material move relative to one another without destroying the continuity of the body. In creating this relative movement, work has to be done to overcome the attractive forces that hold the molecules together. The origin of the elastic properties of a fluid can be found in the attractive forces between molecules which hold these molecules together and thus assure continuity of the material. To displace the molecules from one equilibrium position to an adjacent one, one has to transfer enough energy to the molecules so that they can move over the energy barrier separating the two positions. This energy transfer takes time. If the applied force lasts only for a time shorter than the time required to transfer the necessary energy, the activation energy, the molecule will not get over the barrier and will only be temporarily displaced from its equilibrium position. Upon cessation of this force, the molecules will fall back to the original positions. The end result is elastic deformation. Conversely, if the deforming force is applied slowly over a relatively long period of time, the molecules will have time to move away from their original position into new ones and the fluid will be permanently deformed, i.e., it will have flowed. Thus, fluids as well as solids can show both elastic and viscous properties depending on the rate of deformation. This type of behavior is generally referred to as viscoelasticity and, according to Maxwell (3), can be visualized as a combination of a spring and dashpot (shock absorber) in series as shown in Fig. 1.

Upon compressing or extending such a combination, the spring will respond first and the dashpot will follow only slowly. At constant extension, the dashpot will gradually relieve the spring tension. The stress in such a system will "relax" along an approximately exponential decay curve. The characteristic constant for this decay is called the relaxation time, t_r, which turns out to equal η/G (the dashpot constant or viscosity divided by the spring constant or elastic modulus) in the case of the Maxwell body. Thus, a lubricant can be visualized to be made up of a very large number of such Maxwell bodies having different spring and

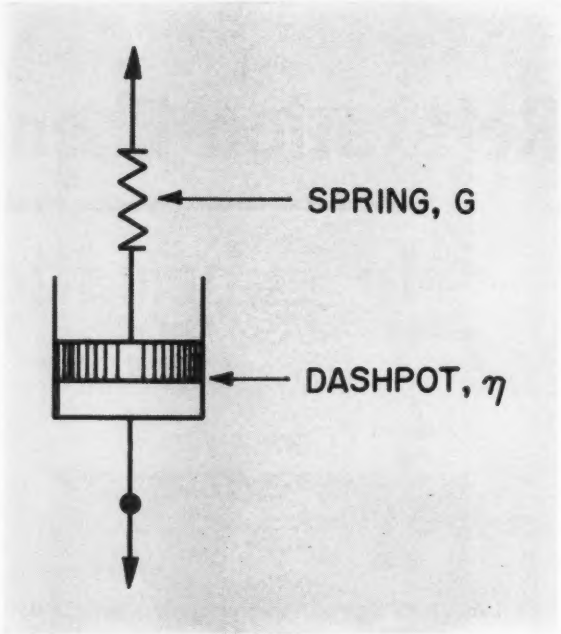


Fig. 1. Mechanical Model of a Viscoelastic Element (Maxwell Body).

dashpot constants and hence, different relaxation times. Thus a substance can be visualized to possess a continuous distribution of relaxation mechanism and associated with each mechanism a certain relaxation time. Depending on the magnitude of these relaxation mechanisms at a given time the substance will exhibit viscous or elastic properties. The time at which the elastic properties will become significant, as indicated by a rapid increase in the value of the distribution function, will be referred to as the "critical relaxation time." This terminology is introduced to distinguish between the simple relaxation times associated with each of the infinitely large number of Maxwell bodies assumed to make up the substance and the critical time when a change in the characteristic macroscopic properties occurs.

DETERMINATION OF VISCOELASTIC PROPERTIES OF LUBRICANTS

Instrumentation

The methods used to determine the distribution of relaxation mechanisms are based on the use of vibrating systems. The basic principle underlying these dynamic test methods is to cyclically deform a sample and analyze the stress-strain relationship under these conditions as a function of frequency. This procedure has been described in detail by Forster and Kolfenbach (4) who used a mechanically-driven cup and plunger system to obtain vibrations of 10^{-4} to 10 cycles per second. To obtain higher frequencies, different means have to be used to produce the vibrating motion. These are either based on electromagnetic principles or the

piezoelectric effect. In the first case (5), a rapidly oscillating magnetic field is produced around the cup and the plunger, acting as a magnet, made to move in it. This equipment covers a range of frequencies from 50 to 5000 cycles/second. In the second case (6), crystals are made to expand and contract at a rapid rate by the application of a high-frequency electric current. Frequencies ranging from 20,000 to 10^9 cycles/second can be reached with this equipment. The selection of the appropriate method will depend on the range of relaxation times one desires to study.

Since increases in frequency entail a decrease in amplitude, one has to be concerned also with the amplitude dependence of the materials under consideration. Greases (4) and similar materials that exhibit large nonlinear, irreversible behavior will show a relatively small frequency dependence but a large amplitude dependence. Straight lubricating oils (7) and polymer-modified oils (6) above their pour point, on the other hand, show very little amplitude dependence but a considerable frequency dependence. To overcome the effect of amplitude dependence, one should in all cases use the value of the elastic and viscous response at each frequency at zero amplitude. This procedure would require a close study of the amplitude dependence at all frequencies and extrapolation to zero amplitude. While this can be done at low frequencies, it becomes practically impossible in the ultrasonic frequency range. To overcome this difficulty, one attempts to increase the power output with increasing frequency so as to operate at least at closely the same amplitude at all frequencies.

In the low-frequency range strain gages are used, but different detecting devices are employed at the higher frequency levels, reflecting the need for faster response to changes in stress and strain. These detecting devices are based on the fact that the electric resistance and reactance of a circuit are the exact analogues of elasticity and viscosity of the sample. No matter what procedure is used to detect the stress-strain relationship, all the experiments are conducted to measure this relationship at various frequencies and to establish the time dependence of both the elastic and viscous responses.

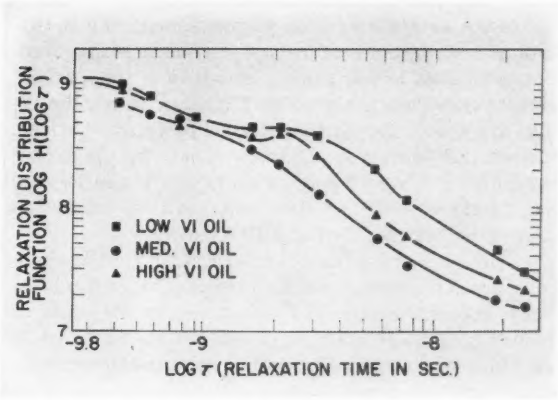


Fig. 2. Distribution of Relaxation Mechanisms in Lubricating Oils (25C)

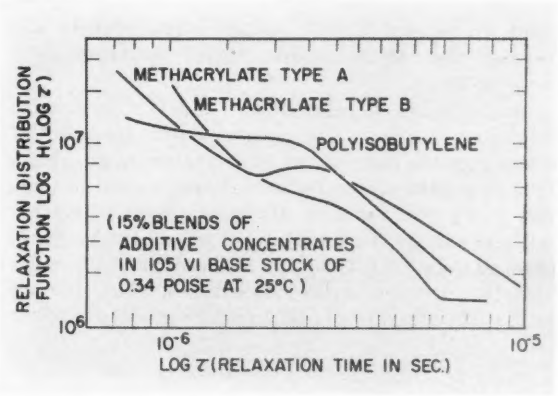


Fig. 3. Distribution of Relaxation Mechanisms in Polymer Modified Oils—(25C). (15% Blends of Additive Concentrates in 105 VI Base Stock of 0.34 Poise at 25C).

Results

Using the ultrasonic techniques described earlier, Lamb (7) found that straight mineral oils exhibit critical relaxation phenomena between 10^{-10} and 10^{-9} seconds. This is shown in Fig. 2, where the distribution of relaxation mechanisms is plotted as a function of time. The low VI oil, a mixture of residual and distillate oils, showed a broad shoulder at about 1.5×10^{-9} seconds, while the medium VI oil, a distillate of average molecular weight of 400, showed a weak maximum around 7×10^{-10} seconds. The high VI oil, also a distillate but of average molecular weight 1000, had a well-defined maximum at 2×10^{-9} seconds. Obviously, the difference between the last two oils was mainly due to the different molecular weights and exemplifies how increasing molecular weight shifts the relaxation mechanisms to longer time intervals.

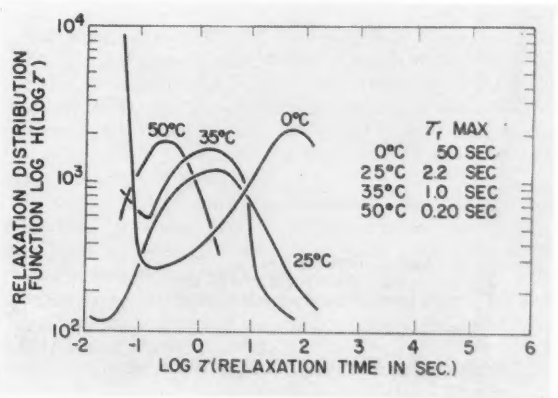


Fig. 4. Distribution of Relaxation Mechanisms in a Lithium—Calcium Soap Grease.

In the author's work on polymer-modified oils (8), similar distributions of relaxation mechanisms were obtained but at longer time intervals than the straight mineral oils. This is shown in Fig. 3, in which the results are shown for three different polymer solutions. One solution contained polyisobutylene; the other two, two different types of polymethacrylate. It can be seen that all three solutions show some critical relaxation phenomena between 10^{-5} and 10^{-6} seconds.

From similar studies (4) on greases using a mechanical vibration tester, it was learned that critical relaxation phenomena occur even with times in the order of seconds. A typical example of the results obtained in this study is shown in Fig. 4 for a lithium-calcium soap grease. At 25° a well-formed critical relaxation time was observed at 2.2 seconds. In this Fig. 4 is also demonstrated the effect of temperature on the relaxation spectrum. A change from 0°C to 50C. causes a change from 50 seconds to 0.2 seconds. Naturally, this temperature effect will depend on the type of system one deals with. In our investigations (4), we encountered other grease systems in which this temperature change over the same temperature region was practically nonexistent. In general, a 50C. change in temperature will decrease the relaxation distribution spectrum by a factor of 25-50.

In the study of these critical relaxation phenomena in lubrication, one is also concerned with the effect of pressure on the distribution of relaxation mechanisms. Very little data are available that can be used to illustrate this point. From the theoretical work of Eyring (1), one can conclude that a thousandfold change in pressure causes a fifty to one hundredfold shift of the relaxation distribution to longer times. Thus, one can see that the pressure and temperature produce opposite effects. By increasing the temperature, one obviously lowers the existing energy barrier and hence facilitates the movement of the molecules over this barrier. Thus, one shortens the relaxation time. Similarly, an increase in pressure would cause an increase in the energy barrier and hence lengthen the relaxation time. Since temperature rises will most likely accompany pressure increases in actual service, this increase in relaxation time due to pressure will be somewhat diminished.

From the data presented so far, as well as those published in the literature, it is possible to develop a composite picture of the distribution of relaxation mechanisms over a time scale ranging from 10^{-12} to 10^{3} seconds. Such a picture is shown in Fig. 5. In producing this figure, it has been assumed, as pointed out in Section II, that the distribution of relaxation mechanisms will be a continuous one. From the curves shown in Fig. 5, it can readily be seen that each type of lubricant, straight mineral oil, polymer-modified oil, and grease, can be characterized by some critical relaxation time at which the contribution of the relaxation mechanisms reaches a significant value. This critical relaxation time can be used as a measure of the time scale on which the elastic properties of the lubricant will become of equal or greater importance than the viscous properties. Thus, one can classify the three types of lubricants in terms of their characteristic critical relaxation times, as shown in Table 1.

TABLE 1—Time Scale on Which Elastic Properties Become Significant

Type of Lubricant	Critical Relaxation Time, Seconds
Lubricating Oils	10^{-11} to 10^{-9}
Polymer-Modified Oils	10^{-6} to 10^{-4}
Greases	10^{-1} to 10

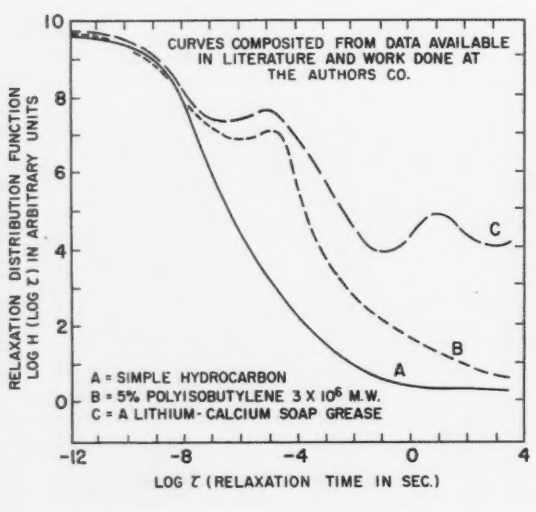


Fig. 5. Distribution of Relaxation Mechanisms in Different Lubricants (25C).

SIGNIFICANCE OF VISCOELASTIC PROPERTIES IN LUBRICATION

The role of viscoelasticity in lubrication has been briefly discussed by O'Donnell (9). The significance of these viscoelastic properties becomes more obvious, however, if one examines more carefully the loading times occurring in bearings and gears under various conditions. Gatcombe, et al. (10), investigated this problem for spur gears and found maximum loading times of about 10^{-6} seconds. The loading times were calculated for ball, roller and journal bearings as well as gears and piston rings for various conditions. The assumptions made in these calculations are shown in Appendix I and the results are summarized in Table 2.

It is interesting to note that these loading times fall in the range of 10^{-6} to 10^{-1} seconds, a range in which polymer-modified oils and greases will show elastic behavior. If the transient time, the time during which the lubricant is subjected to the buildup of maximum load (half the loading time shown), is the same or less than the critical relaxation time, then the lubri-

TABLE 2—Lubricant Loading Time of Bearings and Gears*

EQUIPMENT	SPEED, RPM	LOAD	LUBRICANT LOADING TIME, SECONDS
Ball Bearings			
In Turbojet Engine	30,000	Constant	8×10^{-6}
In Front Wheel of Car	600	Constant	1×10^{-2}
Journal Bearings			
In Gas Turbine	12,000	Constant	5×10^{-4}
In Connecting Rod	3,000	Oscillating	3.3×10^{-4}
In Ships Propeller Shaft	60	Constant	1×10^{-1}
Gears			
In Turboprop Reduction Gear, pitched 3″ x 6″	10,000	Constant	10^{-6}
In L-37 Test, 8.5″ x 1.5″	600	Constant	10^{-4}
Piston Rings	3,000	Variable	10^{-2}

*Basic assumptions and details of calculations are shown in Appendix I.

cant will behave elastically rather than viscuously. As a consequence, the film will not be squeezed out and hence will prevent metal-to-metal contact. Such an elastic film will thus reduce wear, and under these conditions, the lubricant will have improved load-carrying capacities. Indeed some limited experimental evidence of the increased load-carrying capacity has been observed by Borsoff (11) in gear lubrication. He found that the load-carrying capacity of oils decreased with increasing speed in the slow speed range, and increased with speed in the high speed range. Attempts to correlate this increased load-carrying capacity of the oils to their pressure-viscosity characteristics were only partially successful and showed that the elastic properties of the oils have to be considered.

From an analysis of the loading times in bearings and gears and from an examination of the characteristic critical relaxation times of various types of lubricants, it appears quite feasible that oils thickened with polymers should have considerably higher load-carrying capacities than straight mineral oils of the same viscosity. To substantiate these qualitative considerations, further studies will have to be undertaken. In particular, it will be necessary to elucidate the simultaneous effect of pressure, temperature, and rate of shear on the viscoelastic properties of lubricants.

APPENDIX I

Basic Assumptions and Typical Calculations of Loading Times in Bearings and Gears

1. Assumptions

a. *Loading zone* in ball bearings is given by the Hertzian stress area. In journal bearings, the loading zone is taken to extend over an arc of 10° except for the connecting rod bearing where it is an arc of 6°.

b. *Loading time* is defined as the time it takes to move across the loading zone.

2. Calculations

Connecting rod bearing of a 1956 V-8 engine

Operating conditions: 3000 RPM, 145 IHP

From bearing load diagram, the max. rate of change of the load between 700 and 710° crank angle was calculated to be 16.3 times as fast (in the opposite direction) as the crankshaft rotation. The time required at this speed to cover 1° crank angle is 5.5×10^{-5} seconds and hence, 3.3×10^{-4} seconds for 6°. In this time interval, the unit change of the load vector is:

$\frac{5.5 \times 10^{-5}}{16.3} = 3.4 \times 10^{-6}$ seconds per degree of crank angle, indicating the high speed of stress application.

DISCUSSION

by J. L. Zakin
Research Dept., Socony Mobil Oil Co., New York

In this paper Dr. Forster has pointed out the coincidence of relaxation times of lubricants with loading times in certain types of machine elements. Where this occurs, we must consider both the viscous and the elastic rather than merely the viscous properties of the lubricant. The relative importance of the two will depend on the time scale of the phenomenon under consideration. For the lubricants cited, relatively short transient times are required for viscoelastic effects to become prominent. For some viscoelastic phenomena like creep or stress relaxation in metals and rubbers, these effects can be observed over much longer time intervals.

As far as lubricants are concerned, their visco-elastic properties have not been widely understood in the past and little investigative work has been done until fairly recently. A number of papers in the last few years have covered specific areas and Dr. Forster and his co-workers have been quite active in exploratory work on both grease and polymer-thickened oils.

A full understanding of how viscoelastic effects of a lubricant affect its load carrying capacities, and the relationships between molecular and crystalline structure and viscoelasticity, can be of great practical use. It could lead to more accurate design of machine elements and to tailor-

making lubricants for particular end-uses. Testimony to the potential value of such knowledge is a proposal being considered by an ASME Sub-Committee on Lubricants to set up an organized theoretical and exploratory experimental investigation over a wide range of lubricant types and response times. Presumably from such an exploratory mapping-out study, fruitful areas for further detailed investigations will be selected.

In Fig. 3, Dr. Forster has shown the effect of polymer additives on the relaxation spectrum of the polymer-oil solution. It is apparent that different polymers have differing effects. It may be possible to find relationships between relaxation phenomena and the amount and type of polymer, its molecular weight, and its molecular configuration in solution. The latter is related to the "goodness" or "poorness" of the oil as a solvent for the polymer, the temperature, and the nature and amount of other components present. From this kind of information, we might be able to formulate polymer thickened oils with polymers designed for a certain range of relaxation times or use combinations of polymers to cover a wide range.

There are two points on which I'd like to have Dr. Forster comment:

1. There is a second hump on the curve for the lithium-calcium grease in Fig. 5 just above 10^{-5} seconds. Do you have any explanation for this?

2. How do you account for the result shown in Fig. 4 in which a change of temperature of 50 C did not cause any change in the relaxation spectrum in one of the grease systems studied?

AUTHOR'S CLOSING REMARKS

The discussor has brought out several interesting points which deserve close attention. In particular, he wonders whether it would be possible to formulate "tailor-made" lubricants which would be useful for a given range of applications falling into given loading times which match the average relaxation time of the lubricant. This is indeed possible, and should become practice as time goes on because the benefits derived from such tailor-made lubricants would be worth the extra cost. But what is more important is the fact that one can also control the extent of the elastic properties by controlling the concentration of the relaxing species within a given viscosity range.

With regard to the two specific points the discussor raises, the following comments are made:

The explanation for the second maximum for the lithium-calcium grease in Fig. 5 is not at all apparent. It could very well be that rather than having a true maximum, one would observe merely a shoulder similar to that shown in Fig. 3 for poly-isobutylene, or in Fig. 2 for the low VI oil. In other words, this curve is subject to experimental elucidation and is merely shown for illustrative purposes.

The reference to the grease referred to in Fig. 4 in which a change of temperature of 50 C. did not cause any change in the relaxation spectrum has been dealt with in Reference(4). For the convenience of the reader, it is stated again that this particular soap system had a structure which was not sensitive to changes of temperature between 0 and 50 C.

In conclusion, the author would like to thank the discussor for ably underlining some of the important aspects that the paper tries to establish.

BIBLIOGRAPHY

1. Eyring, H., Hahn, S. J., Higuchi, I., and Ree, T., "Flow Properties of Lubricating Oils Under Pressure," *NLGI Spokesman* 22, No. 3, pp. 21-8 (June 1958).
2. Pressure-Viscosity Report, A Report of the ASME Res. Com. on Lubrication, Am. Soc. of Mech. Eng. (1953).
3. Maxwell, Scientific Papers, Vol. 2, "Dynamic Theory of Gases," 1867, p. 31.
4. Forster, E. O., and Kolfenbach, J. J., "Viscoelastic Behavior of Greases," Transactions of the ASLE, Vol. 2, No. 1 (April 1959).
5. Fitzgerald, E. C., and Ferry, T. D., "Method of Determining the Dynamic Mechanical Behavior of Gels and Solids at Audio-Frequencies; Comparison of Mechanical and Electrical Properties," J. Coll. Sci. 8, 1-34 (1953).
6. Chapter IV "Physical Acoustics and the Properties of Solids, Mason, W. P., D. Van Nostrand Co. (1958).
7. Barlow, J., and Lamb, J., "Ultrasonic Techniques for Determination of Shear Mechanical Impedance of Lubricating Oils," Paper presented before the Relaxation Processes Symposium of the Faraday Society, London, Nov. 27, 1958.
8. Horowitz, H. H., Steidler, F., and Forster, E. O., "Bearing Performance and Elastic Properties of Polymer-Thickened Lubricating Oils," Proceedings of the 5th World Petroleum Congress, Section VI, 1959 (in press).
9. O'Donnell, G. J., "Viscoelasticity in Lubrication," *Mechanical Engineering* 81, No. 2 (Feb. 1959), pp. 63-5.
10. Gatcombe, E. K., Hunnicutt, R. P., Kinney, G. S. "Spur-Gear-Hertzian Contact Times," *Lubrication Engineering*, Vol. 16, No. 7 (July 1960) pp. 308-311.
11. Borsoff, V. N., "On the Mechanism of Gear Lubrication," Trans. ASME-J. Basic Engineering (1959) (in press).

Engine Rusting in Service and Dynamometer Tests

by Paul A. Bennett
General Motors Research Laboratories
Warren, Michigan

The paper presents field test experience showing that severe rusting of critical engine parts may occur at very low mileages in short-trip passenger-car service.

A dynamometer engine test procedure is presented which correlates with field experience. In addition, data are presented which illustrate the importance of several engine operating variables on engine rusting tendencies in the full-scale engine test. Close control of such variables as carburetor air humidity, blowby rate, fuel composition, and engine speed, load and operating temperature is necessary if consistent results are to be obtained.

INTRODUCTION

Mougey (1) has referred to the problem of rusting and corrosion of internal engine parts as ". . . one of the earliest problems encountered in automotive lubrication . . ." and has reported that although the problem existed before 1920, very little was published about it until about 1924. Since that time the development and use of thermostats (2), improved crankcase ventilation systems (3, 4), and additive-treated oils (5, 6) have reduced the problem to tolerable levels under most engine operating conditions. However, the problem has not been completely resolved. Corrosive wear may still occur under low-temperature operating conditions or during start-up (7, 8).

Although most corrosion studies have considered only the problem of piston ring and cylinder wear, general engine corrosion has been attracting increased attention during the last decade. This has resulted from (a) the increased use of close-fitting parts such as hydraulic valve lifters in automotive engines, and (b) the realization that the automotive engine lubrication problem is predominantly a low-temperature problem.

Presented at the 15th ASLE Annual Meeting, Cincinnati, Ohio
April, 1960

The objectives of this paper are to present some of the background behind the development of an engine test which has been used to evaluate the antirust or anti-corrosion performance of automotive engine lubricants (9, 10), to show the correlation of the engine test results with short-trip service data, and to discuss some of the important test variables.

EQUIPMENT AND PROCEDURES

The rusting or corrosion of internal engine parts which occurs at low-temperature operating conditions includes a number of different chemical reactions, a discussion of which is beyond the scope of this paper. This general low-temperature problem will be referred to as "rusting" primarily to distinguish it from high temperature corrosion.

Short-Trip Tests

The short trip service tests were conducted during a 3-month period early in 1959. The test cars were new 1959 automobiles. Following a break-in on factory-fill oil, the cars were driven in home-to-work transportation service with a maximum trip length of 4 miles. The cars were parked outside at all times and a commercial premium grade gasoline having a sulfur content of 0.02 weight percent was used. The drivers were rotated daily and were required to abide by the following regulations:

1. No car was driven more than 4 miles at any one time.
2. The accumulated mileage could not exceed 4 miles in any 4-hour period.
3. No car was driven more than 40 mph at any time.
4. Idling was not permitted except as necessary in traffic.

The Engine Dynamometer Test

The engine dynamometer rusting test is one of the ASTM G-IV engine test Sequences (9, 10). The test consists of 3 hours of operation at engine temperatures such that acidic blowby condensates accumulate in the engine crankcase, followed by a 3-hour shutdown under controlled conditions. The test procedure is summarized in Appendix A.

The engine test data were obtained using several engine makes and with minor variations of the basic procedure described in the Appendix. These engine variations will be indicated in the text.

Rust Ratings

Engine rusting tendencies are reported in terms of average rust ratings of the hydraulic valve lifters. In general, hydraulic valve lifter rusting correlates with average engine rusting tendencies. Valve lifters are rated using a scale ranging from 0 for a part completely covered with a heavy layer of rust to 10 for a rust-free part. Deposits or stains are reported as rust if they were not removed by washing in acetone but could be removed by a 20/40/40 mixture of phosphoric acid, denatured alcohol, and water.

Oil Analysis Procedure

The used oil analysis presented in Fig. 5 was obtained using the following procedure. The oil samples were centrifuged with normal Pentane using the ASTM D-893 Insolubles test procedure. The supernatant liquid was filtered using an 0.8 micron millipore filter. The Pentane diluent was evaporated from the filtrate and an elemental analysis made of the clarified sample using ASTM spectrographic procedures (11).

TEST LUBRICANTS

The service tests were conducted using four commercial lubricants designated by the refiners as oils for MS Service. Three of the oils were premium-priced, first-line, multi-grade products and one was a second-line oil. The principal physical and chemical properties of the oils are shown in Table 1.

TABLE 1—Physical and Chemical Properties

TEST OILS	A	B	C	D
SAE Grade	10W-30	10W-30	20W	10W-30
Vis. at 100 F (CS)	66.2	74.0	73.5	63.9
Vis. at 210 F (CS)	10.60	11.55	8.85	11.93
VI	137	136	102	143
TAN	2.52	1.89	0.61	2.31
TBN	1.80	5.01	1.41	0.29
Barium (%)	0.72	0.95	0.35	None
Calcium (%)	Trace	Trace	Trace	Trace
Phosphorus (%)	0.085	0.11	0.10	0.11
Zinc (%)	0.088	0.094	0.09	0.13

The engine dynamometer data include results obtained using the oils of Table 1 as well as other commercial and non-commercial products.

DISCUSSION AND RESULTS

Short-Trip Service Tests

The best performance evaluation of an automotive lubricant is, of course, the performance in full-scale equipment operated by the motoring public. The major disadvantage of such tests is the time required. Accordingly, controlled field tests have become widely used for evaluating commercial lubricants.

The most common type of service crankcase lubricant performance test is the taxi fleet test (12). These tests are of value in that they accumulate considerable mileage in a short period of time. Although engine temperatures are relatively low in the usual taxi fleet operation, engine operating time is a significant portion of the total elapsed time. Such operation differs considerably from that of many individual car owners. Fig. 1 shows that the majority of passenger car trips are short length trips where engine shut-downs constitute the major portion of the total time. The net effect of these differences is that the fleet or taxi service test may emphasize the lubricant sludge and varnish handling properties while largely ignoring anti-rust performance. In many cases it is necessary to supplement such fleet test data if all desired lubricant performance qualities are to be evaluated.

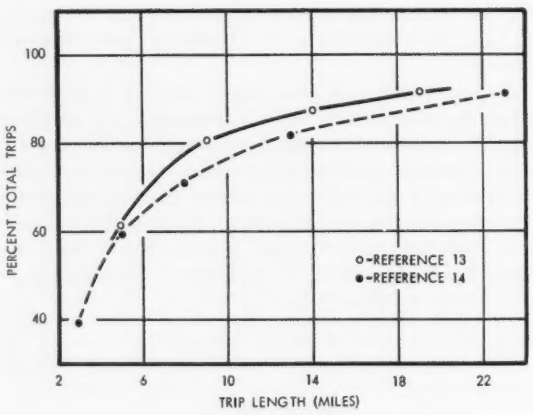


Fig. 1. Distribution of Passenger Car Trips in Terms of Trip Length.

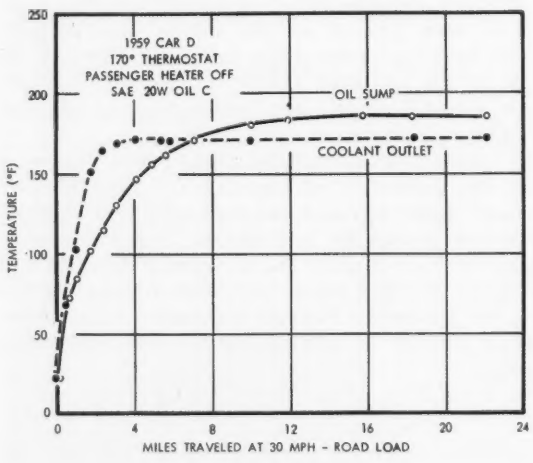


Fig. 2. Engine Warm-Up After an Overnight Soak at 22F.

In contrast to the normal taxi or fleet service test, service tests can be designed to emphasize short-trip operation which more nearly simulates the driving habits of the individual car owner. The data of Figure 1 indicate that some 50 percent of all trips are of less than 4 miles duration. A 4-mile winter trip under average urban driving conditions is not long enough to bring the engine coolant and lubricant to normal operating temperatures. For example, Fig. 2 shows that at 30 mph the engine oil temperature may not stabilize in less than 12 miles. Operation under short-trip conditions emphasizes engine rusting tendencies and has been used to evaluate the anti-rust performance of commercial lubricants.

The results of a short trip test using a 4-mile maximum trip length schedule, which is perhaps the most severe type of service rusting test, are presented to:

1. Illustrate the rapidity with which engine rusting can occur in some severe types of service.
2. Show the variation in oil quality possible with widely used commercial oils.
3. Provide service performance data for use in developing engine dynamometer tests.

Service Test Results: Engine valve lifters were removed at intervals during the test and inspected for evidence of sticking and rusting. The results are summarized in Fig. 3 and Table 2. Table 2 presents the average valve lifter rust ratings at 3 mileages during the test. Photographs of representative lifters for each of the oils at the time of inspection are shown in Fig. 3.

TABLE 2—Average Valve Lifter Rust Ratings
1959 car d

Test Oil	Test Miles		
	160–185	390–415	485–560
A	10.0	10.0	10.0
B	10.0	9.2	8.5
C	9.9	9.5	8.4
D	7.4	5.8	5.5

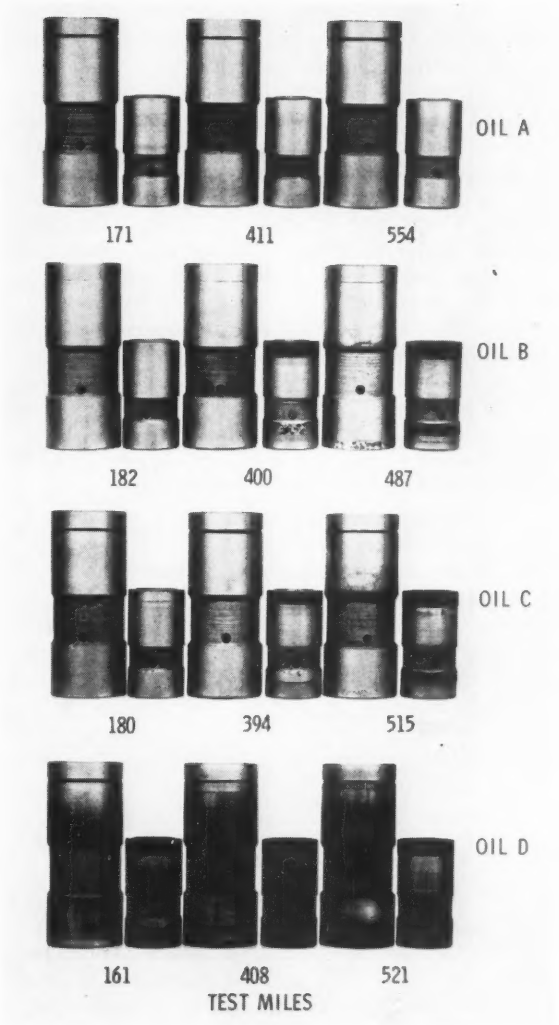


Fig. 3. Effect of Commercial Lubricants on Valve Lifter Rusting Tendency in Short-Trip Service.

Although there were slight differences in test mileages at the time of inspection, wide differences in oil performance were observed. With some oils the engines were completely rust-free after 500 to 600 miles of operation as shown by the data for Oil A. On the other hand, some commercial lubricants result in considerable rusting in as few as 160 miles (about 4 weeks) in this particular service. After about 2 months of operation, the plungers of valve lifters operated on Oil D, although free to rotate, were stuck in their normal operating ranges and would not move axially in the lifter body. The lifters could be disassembled only by driving the plunger from the lifter body. With Oils B and C sufficient rusting occurred in 500 miles (about 3 months) to necessitate driving the plunger from the lifter body.

The short-trip test data illustrates the great differences in anti-rust performance resulting from the use of different commercial automotive engine lubricants. While not only oil quality but engine condition, the type of service, and the oil change interval are important factors in the rusting problem, acceptable lubricants should be capable of operating for at least a few weeks (even under severe conditions) without appreciable attack of metal surfaces. Oils such as D are hopelessly deficient in engine and anti-rust performance. Alternately, oils such as A, B, and C are representative of lubricants resulting in good to excellent anti-rust performance.

The Engine Dynamometer Rusting Test

The need for engine dynamometer tests to simulate the short-trip service test is obvious when the time required to accumulate the field test data is considered. The suitabiilty of engine dynamometer tests for evaluating the anti-rust performance of crankcase lubricants was recognized several years ago by Mougey (1) who proposed a test that had been used for some time for evaluating initial-fill lubricants.

Basically, the engine rusting test is a modification of the procedure proposed by Mougey and consists of operation under conditions such that acidic materials condense from the blowby gases and accumulate in the engine crankcase. By proper choice of the engine operating temperatures the amount of condensate accumulated under steady state conditions approximates the contaminants condensed in service under short-trip conditions. In effect, the engine dynamometer test prolongs engine warm-up to simulate, in a few days, the results of several months of short-trip service operation.

Comparison of Service and Dynamometer Test Results: A comparison of the results of the service and dynamometer tests are presented in Table 3. Data are presented for the oils previously evaluated in the short-trip tests. Table 3 shows that the dynamometer engine test procedure satisfactorily correlates with the short-trip service test with respect to:

1. Used oil fuel dilution.
2. Used oil water content, and
3. Hydraulic valve lifter rusting tendencies.

The engine rusting test provides the same ranking of oils with respect to rusting tendency as has been observed in field tests, and provides this evaluation in a much shorter period of time.

TABLE 3—Comparison of Road and Dynamometer Test Results

	Short-Trip Test 1959 Car D	Engine Test 1959 Engine F
Elapsed Time	3 Months	1 Week
Average Used Oil		
Fuel Dilution (%)	10-14	4-8
Water Content (%)	0.02-0.10	0.04-0.10
Average Hydraulic Valve Lifter Rust Ratings		
Oil A	10.0	10.0
Oil B	8.5	9.4
Oil C	8.4	8.5
Oil D	5.5	5.0

Test Repeatability: A factor of considerable importance in any test procedure is that of repeatability. Obviously, any test which will not give consistent results is of limited value. This is especially important in engine rust tests since, because of the large number of variables, considerable care is necessary to obtain consistent results. Fig. 4 presents the results of repeated tests of miscellaneous commercial and factory-fill lubricants. The test-to-test variation in average lifter rust ratings ranges from about ± 0.2 number for oils resulting in essentially rust-free parts to ± 0.5 number at an average lifter rust rating of 7. This repeatability, which is within the accuracy of the rust rating procedure, is considered acceptable.

Additive Depletion and Stability: The engine dynamometer test provides a means of subjecting crankcase oils to operation in the presence of blowby contaminants in much the same way that they are required to perform in many types of service. Since operation in the presence of blowby contaminants can affect the stability and depletion rates of additives, the test provides a means of studying these additive characteristics.

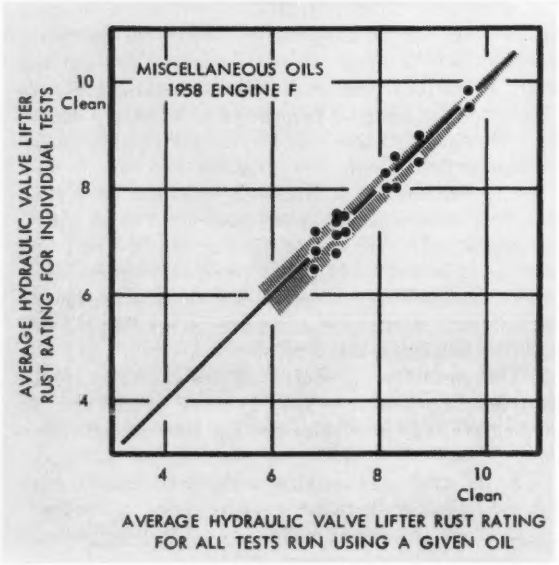


Fig. 4. Variation of Hydraulic Valve Lifter Rust Ratings.

Such a depletion and stability comparison is shown by the data of Fig. 5. Oil E is typical of a group of commercial MS lubricants which use barium sulfonate detergents and zinc dithiophosphate inhibitors. Spectrographic analysis of the lubricating oil samples obtained at intervals during the test show a general depletion of barium with test time as shown by Fig. 5a. The same graph indicates a similar decrease in used oil zinc content. These data illustrate that the particular detergent used in this oil is quite stable (showing a relatively small depletion with test time). The wide differences in the zinc and phosphorus contents of the used oil indicate that the zinc dithiophosphate decomposed.

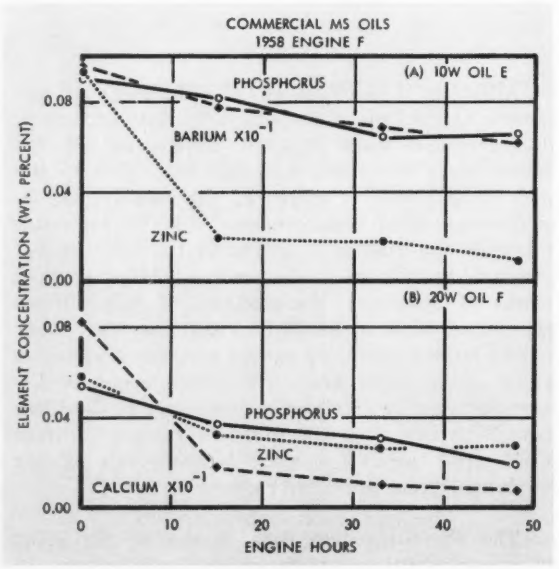


Fig. 5. Additive Depletion and Stability.

Fig. 5b shows a much more rapid depletion of the calcium in Oil F than the barium depletion observed for Oil E. However, the zinc dithiophosphate inhibitor used, while exhibiting some depletion with test time, was much more stable under these test conditions as indicated by the similarity of the zinc and phosphorus curves. Information concerning the stability and depletion rates of lubricant additives under known operating conditions can be useful in evaluating the performance of engine lubricants.

Some Important Operating Variables in the Engine Rust Test

Although engine rusting tests have been used throughout both the automotive and petroleum industries, one of the primary problems has been that of poor repeatability. This, of course, indicates a lack of control of important test parameters. Although considerable work remains, progress has been made in defining some of the important variables in the engine test. The results of a portion of this work are described below.

Carburetor Air Humidity: During the development of the engine dynamometer test, a definite correlation of carburetor air humidity and engine rusting tendency was observed. As shown by the data of Fig. 6, rusting increased with carburetor air moisture content. At first thought these data seemed difficult to justify because of the high moisture content of engine exhaust gases. However, this supposition implies that engine blowby gases are largely exhaust products. This is not the case. The literature (15, 16) and Table 4 indicate that blowby and exhaust products differ widely in composition. Consideration of these facts led to the conclusion (17), as discussed in Appendix B, that engine blowby gases are largely carbureted mixture diluted with unscavenged combustion products. Variation in carburetor air humidity can result in significant changes in the amount of moisture passing the piston rings with the blowby gases, and in definite changes in engine rusting tendencies.

TABLE 4—Composition of Blowby and Exhaust Gases
1958 engine F

Composition, Vol. % (Orsat)	CO_2	O_2	CO
Exhaust Gas	13.1	1.5	0.3
Blowby Gas	2.7	16.5	0.1
Engine Operating Conditions			
Speed	1500 rpm		
Load	25 bhp		
A/F	16.2		
Fuel H/C	2.0		
Carburetor Air Humidity	80 grains/pound dry air		
Blowby Rate	0.5 cfm		
Blowby Moisture Content at Road Draft Tube With Oil Filler Pipe Plugged	130 grains/pound		

Engine Blowby Rates: The effect of engine blowby rates on valve lifter rusting tendency is illustrated by the data of Table 5. These data show that variations in blowby rate can result in significant changes in engine rusting tendencies.

TABLE 5—Effect of Blowby Rate on Hydraulic Valve Lifter Rusting
1958 engine F
commercial MS oil H

Blowby Rate, CFM	Average Rust Rating
0.6	10.0
0.8	9.8
1.0	8.8
1.2	7.2

Other Important Test Variables: The fact that engine blowby gas is a mixture of fresh or partially oxidized fresh charge diluted with a small amount of exhaust gas indicates a need for close control of a number of engine operating variables. The need for close control of fuel type and composition, because of the effect of the products of combustion on corrosion, has been generally recognized (2, 18, 19). In addition, the fuel and the fuel additives may directly affect engine corrosion rates since a significant amount of unburned fuel is present in the engine blowby gases.

TABLE 6—Variation in Blowby and Exhaust Gas Composition with Engine Speed and Load
1958 car C—oil filler pipe plugged

Condition	CO_2	O_2	CO	Air/Fuel	Ratio $\frac{\text{Blowby } CO_2}{\text{Exhaust } CO_2}$
Idle (Drive)				11.8	0.31
Exhaust	8.1	2.8	6.5		
Blowby	2.5	12.0	0.4		
30 mph—Road Load				14.5	0.20
Exhaust	12.2	3.6	0.2		
Blowby	2.4	16.2	1.1		
50 mph—Road Load				14.0	0.16
Exhaust	13.3	2.1	0.1		
Blowby	2.1	17.2	0.6		

Engine air-fuel ratio is an important variable affecting blowby gas composition. In addition, control of the composition of the blowby gas can be achieved only if engine speed and load are controlled. The composition of the blowby gas will vary with engine operating conditions as indicated by the data of Table 6. Using the ratio of blowby gas CO_2 to exhaust CO_2 as a measure of the exhaust gas in the blowby, Table 6 indicates that the amount of exhaust gas in blowby may vary considerably with engine operating conditions.

The composition of the crankcase gases is also affected by leaking engine seals and gaskets. Leaks can result in appreciable changes in the composition of the atmosphere inside the engine crankcase and significantly affect engine rusting tendencies.

Finally, it is obvious that the rate of condensation of fuel, water, and acidic blowby contaminants will vary considerably with engine operating temperatures. In short, consistent results can be obtained only if all engine operating variables are closely controlled.

SUMMARY

Service tests have been presented which show that severe hydraulic valve lifter rusting can occur in short-trip operation and that engine lubricants vary widely in anti-rust performance. Some commercial lubricants result in objectionable rusting in as little as 160 miles (one month) whereas others result in rust-free performance for more than 500 miles (3 months) in the same service.

An engine dynamometer test is presented which simulates the results of the short-trip service test. The MS engine rust test ranks lubricants in the same order as the service tests, provides the evaluation in a much shorter period of time, and with acceptable repeatability.

It has been shown that carburetor air humidity is an important test variable since rusting tendencies increase with air moisture content at normal atmospheric humidity levels. Also, within the range of normal engine blowby rates, engine rusting increases with increasing blowby.

Because of the large number of variables which can affect engine rusting and corrosion, careful control of all engine operating variables is required to obtain consistent results. However, the fact that engine blowby gases are predominantly carbureted mixture can explain the experimental observations. An appreciation of this fact has resulted in improved test repeatability.

Finally, the observation that blowby gases are predominantly carbureted mixture accounts for the well-known effect of fuel on engine lubrication requirements and suggests that fuel additives may provide a means of controlling engine rusting.

REFERENCES

1. Mougey, H. C., "Forty Years of Progress in Automotive Lubrication—A Look into the Future," SAE Transactions, 62 (1954) p. 196.
2. Georgi, C. W., "Motor Oils and Engine Lubrication," Reinhold Publishing Corp., (1950).
3. Moir, H. L., and Hemmingway, H. L., "Effect of Crankcase Ventilation on Engine Deposits," SAE Quarterly Transactions, (1947) p. 389.
4. Brown, B. G., "Taking the Guess-Work Out of Crankcase Ventilation," SAE Quarterly Transactions, (1949) p. 18.
5. Palmer, J. L., "Effect of Heavy-Duty Oils on Engine Wear in Typical Passenger-Car Service," SAE Transactions, 61 (1953) p. 237.
6. Jackson, H. R., "Laboratory and Field Wear Tests Using Radioactive Tracers," SAE Transactions, 61 (1953) p. 233.
7. Edgar, J. A., "Control of Wear in Piston Engines," Proceedings of the Conference on Lubrication and Wear, Institution of Mechanical Engineers (1957) p. 497.
8. Batzold, J. S., Clarke, J. V., Jr., and Kunc, J. F., "Continuous Radiotracer Monitoring Shows How Piston Rings Wear in Service," SAE Transactions, 66 (1958) p. 602.
9. "Engine Test Sequences for Evaluating Oils for API Service MS," Report of ASTM Subcommittee G-IV (1959).
10. "Procedure for Evaluating the Engine Performance Characteristics of Crankcase Oils for Most Severe Service," General Motors Manufacturing Standards, Materials and Processes, GM-4477P.
11. "Rotating Disk Electrode Technique," Method Described in Appendix of ASTM E-22 Standard on Spectro-Chemical Methods, Revised (1957).
12. Bardy, D. C., and Wallace, J. C., "Taxicabs in Motor Oil Field Testing." Presented at the National SAE Fuels and Lubricants Meeting, Tulsa, November (1958).
13. Bostick, T. A., Messer, R. T., and Steele, C. A., "Motor-Vehicle-Use Studies in Six States," Public Roads 28 (1954) p. 99.
14. "The Automobile in the Daily Life of the American Population," A Survey conducted for the Automobile Manufacturers Association by Alfred Politz Research, Inc. (1951).
15. Payne, J. Q., and Sigworth, H. W., "The Composition and Nature of Blowby and Exhaust Gases from Passenger Car Engines," proc. of the 2nd National Air Pollution Symposium (1952) p. 62.
16. Cutter, D. C., "A Study of Blowby in the Internal Combustion Engine," Unpublished Thesis for the Degree of Mechanical Engineer, Yale University (1933).
17. Bennett, P. A., Jackson, M. W., Murphy, C. K., and Randall, R. A., "Reduction of Air Pollution by Control of Emission from Automotive Crankcases," Presented at the SAE Annual Meeting, Detroit, January 1960.
18. Williams, C. G., "Collected Researches on Cylinder Wear," Institution of Automobile Engineers (1940).
19. Randall, T. H., Andrus, R. E., Fein, R. S., and Kluge, H. D., "Lubricant Additive Action in Combating Low-Temperature Wear in Automotive Engines," Presented at the SAE National Fuels and Lubricants Meeting, Tulsa, November (1958).
20. Clayden, A. L., "Water in Crankcase Oils," SAE Transactions 19, Part 2 (1924) p. 58.

APPENDIX A
THE DYNAMOMETER ENGINE RUSTING TEST (10)

SCOPE

The engine test evaluates the low-temperature corrosion tendencies of automotive engine crankcase lubricants under simulated short-trip operating conditions.

take advantage of Lubrication Engineering's reader service department now!

Postage Will Be Paid by Addressee

No Postage Stamp Necessary If Mailed in the United States

BUSINESS REPLY CARD

First Class Permit No. 41874 (Sec. 34.9, P.L. & R.) Chicago, Illinois

LUBRICATION ENGINEERING

American Society of Lubrication Engineers, Publisher

5 North Wabash Ave.

CHICAGO 1, ILLINOIS

For your convenience . . .

LUBRICATION ENGINEERING'S READERS' SERVICE DEPARTMENT

. . . makes it easy for you to get more information about the items mentioned in the New Products and Product Literature Departments in this issue. Simply circle the numbers on the Readers' Service Reply Card that corresponds with the number under each item featured in New Products and Product Literature, drop the card in the mail, and within days you will receive the information requested.

November, 1960

LUBRICATION ENGINEERING'S READERS' SERVICE CARD

This card expires December 31, 1960

Please have information sent to me on items circled below:

1	2	3	4	5	6	7	8	9	10	11	12
13	14	15	16	17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32	33	34	35	36

My Name_____ Title_____

Company Name_____

Address_____

City_____ Zone_____ State_____

OPERATING PROCEDURE

The engine is operated for 3 hours under the following test conditions with the oil filler tube plugged:

Speed	1500 ± 20 rpm
Load	25 ± 2 bhp
Coolant Out	95 ± 2F
Coolant In	85F minimum
Oil Sump	120 ± 2F
Blowby Rate	0.6 ± 0.1 cfm
Carburetor Air Humidity	80 ± 5 grains/# dry air
A/F	16.0 ± 5

The engine is then shut down for 3 hours with the coolant maintained at 95F. This cycle is repeated for a total of 16 cycles.

APPARATUS

Test Engine

The test engine is a production 1958 automotive V-8 engine equipped with a 2-barrel carburetor.

Lubricating oil filters are not used.

Engine Coolant System

A suitable external engine coolant system is necessary to maintain the required coolant temperatures during both the firing and soak portions of the test schedule.

Eingine Oil Cooling System

An externally driven pump and a suitable heat exchanger are required to maintain the desired oil temperature. Suitable fittings must be correctly located in the engine oil pan to accommodate the oil lines.

Air-Fuel Ratios

Engine air-fuel ratios are determined by Orsat analysis of the exhaust gases.

Blowby

Suitable equipment is needed for indicating blowby rates while maintaining engine crankcase pressure between 0.0 and 0.2 in. of water. Engine blowby rates are measured at the road draft tube with the engine oil filter tube and dipstick guide tube plugged.

FUEL

The fuel is a mixture of 75% MIL-F-5572B Grade 80 and 25% of a particular commercial-type gasoline. The blend contains 3.0 ml TEL/gallon and 0.16 ± 0.02% (wt) sulfur. The fuel sulfur level is obtained by adding the necessary amount of Ditertiary Butyl Disulfide.

OIL ADDITIONS AND SAMPLING

The total crankcase oil charge is maintained between 4.5 and 5 quarts throughout the test. The methods used for checking the oil level, making oil additions, and obtaining the oil samples are specified.

APPENDIX B
THE EFFECT OF CARBURETOR AIR HUMIDITY ON ENGINE RUSTING TENDENCY

As discussed briefly in the text, the observation that variations in carburetor air humidity influenced engine rusting tendency (Fig. 6) seemed, at first thought, to conflict with reason. For example, there has been a general conviction that engine blowby gases are largely exhaust products. Studies of the rate of moisture condensation from engine blowby gases have considered the water to result from condensation of the products of combustion on the cold engine surfaces. Clayden (20) in discussing his own work in 1924 ascribed the water which condensed in the engine oil to this source stating ". . . the major portion of the leaking gases will condense, since the principal product of the combustion of gasoline is water." This explanation has been commonly accepted since that time.

On the other hand, the assumption that the water in the blowby condensate was formed during combustion of the fuel implies that the blowby gas is essentially all combustion products. This is not the case. Information is available (15, 16) which indicates that blowby and exhaust products differ widely in composition.

These differences in composition have been illustrated by the data of Table 4. Although the data could be explained by assuming the blowby gas samples to be diluted with air, sealing and pressurization of the crankcase and sampling under conditions such that air dilution could not occur resulted in no change in the analysis. It was concluded that the blowby gas composition of Table 4 was representative of the composition of the gases leaking past the piston rings and that the high oxygen content of the blowby gas resulted from dilution of the residual exhaust products in the combustion chamber by the fresh fuel-air charge.

Accordingly, as a first approximation, it was assumed that the blowby gas is a mixture of fresh charge diluted with unscavenged products of previous cycles. This assumption has been substantiated by recently reported work (17). Thus, the ratio of blowby gas CO_2 to exhaust gas CO_2 provides an estimation of the concentration of the exhaust products in the blowby gas. The data of Table 4 indicate that about 20% (2.7/13.1) of the blowby gas was exhaust products. The remaining 80% was assumed to be largely fresh charge.

The above discussion implies that the moisture content of the exhaust gas accounts for only a part of the moisture content of the blowby gas with the moisture content of the carburetor air determining the remainder. Assuming that no moisture condensation occurs in the combustion chamber, it is clear that the moisture content of the carburetor air could exert an appreciable effect on the blowby gas moisture content.

For example, from the data of Table 4 and the combustion equation, the exhaust gas moisture content was calculated to be about 665 grains moisture per pound of dry exhaust gas. Allowing for the relative amounts of fresh charge and exhaust products in the blowby gas, the total moisture content of the blowby gas at the ring belt was about 200 grains per pound for a carburetor air humidity of 80 grains per pound ($0.20 \times 665 + 0.80 \times 80$).

In addition, at these engine conditions the moisture content of the blowby gases at the crankcase road draft tube, with all other crankcase openings plugged, was about 130 grains per pound. Accordingly, it was estimated that about 70 (200-130) grains of moisture could condense in the crankcase for each pound of blowby gas passing through the engine.

Similarly, at a carburetor air humidity of 60 grains per pound the moisture content of the blowby gases at the ring belt was calculated to be about 175 grains per pound. This change in blowby gas moisture content is consistent with the differences in engine rusting tendencies shown in Fig. 6.

It has been concluded that the variation of engine rusting tendency with carburetor air humidity can be explained by the fact that engine blowby gases are predominantly carbureted mixture diluted with a small amount of exhaust products. In addition, this observation has pointed out the need for close control of engine operating variables if consistent engine test results are to be obtained, it explains the widely recognized effect of fuel type of engine sludge and varnish deposition (2), and has a number of engine lubrication requirement implications.

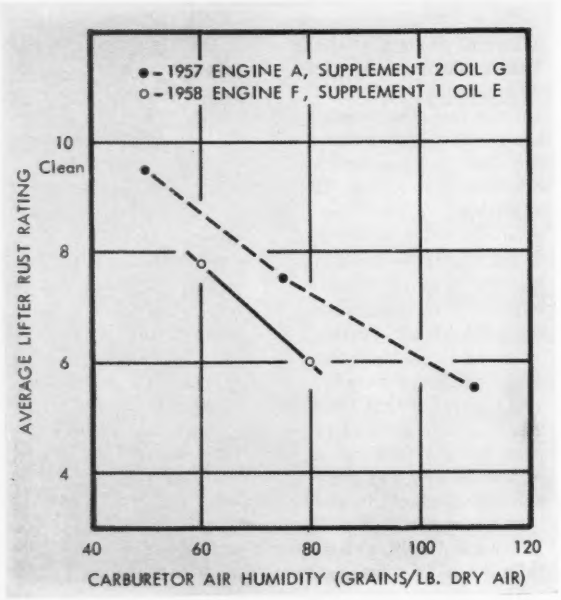


Fig. 6. Effect of Carburetor Air Humidity on Hydraulic Valve Lifter Rusting.

DISCUSSION

C. C. Colyer and T. B. Tom
Research and Development Department, Standard Oil Company (Indiana), Whiting, Indiana

Modern engines are made to deliver high horsepower, and if this were the only service demanded of them, suitable motor oils could be formulated without concern for rust inhibition properties. But most of the time these engines loaf under light-load, low-temperature, short-trip operation. The engine seldom runs hot enough to prevent condensation of combustion products or to get rid of them once they are formed. Corrosion sets in, and grows worse as the engine cools during shutdown. Thus, today's motor oils must provide protection against rust deposits in order that close-tolerance engine parts, such as hydraulic-valve lifters, will function properly.

Years ago we developed a laboratory engine rust test, somewhat similar to the MS Sequence II test, that was used in our motor oil development work. The results from our test are comparable with those from the MS test. Passing either of these tests does an excellent job of guaranteeing against excessive rust in service. We are content henceforth to use the more universally accepted MS procedure. We compliment the author in his attempts to improve test repeatability by controlling intake-air humidity, engine blowby, and air-fuel ratio.

Mr. Bennett feels that in most taxicab field tests the investigator ignores anti-rust performance. It is true that the large amounts of sludge and varnish deposits found in taxicab engines often obscure rust deposits. However, in a recent taxicab field test, we analyzed the sludge for iron content and found one test oil gave sludge deposits containing six times as much iron as did the other test oils. This was the only oil in the series that had failed the MS rust test. All the test oils gave similar wear data.

In comparing laboratory MS test results with results from other types of field tests we find that engine make has an effect on the degree of rust deposits, however the relative ratings of various oils are not affected by engine make. Two makes of late model cars were run under city-commuter driving conditions with two commercial oils that passed the MS rust test. In one make the rust ratings of both oils were the same as predicted by the MS test while in the second make one oil rated as predicted and the other oil gave slight rust deposits.

TABLE A1. City-Commutor Driving

OIL	RUST RATING MS	CAR X	CAR Y
A	Good	Good	Good
B	Good	Good	Fair

In conclusion we would like to put a question to Mr. Bennett. The California decision to feed engine blowby back into the carburetor to reduce smog is receiving a great deal of attention. We would like to know if the author has any data on how this modification affects engine rust deposition?

TABLE A2. Phosphorus Content of Used Oils

	PHOSPHORUS IN OIL, % WT. NON-P FUEL	P FUEL
New Oil	0.20	0.20
72 Hours	0.17	0.32

Phosphorus was one of the additive elements used by Mr. Bennett to study the depletion rates of additives. When non-phosphorus fuels are used, as in the author's case, phosphorus measurements can be used satisfactorily to show additive depletion. However we would like to caution against using motor-oil phosphorus content when studying additive depletion with phosphorus-containing fuels. In laboratory engine tests we found that the use of phosphorus fuels increased the phosphorus content of the used oil 50%.

AUTHOR'S CLOSING REMARKS

The discussers' comment concerning the iron content of sludge is very pertinent to the low-temperature corrosion problem. Although the iron content of used oil or sludge may not necessarily result from the corrosion of engine parts, under low-temperature operating conditions the "wear" of certain engine parts may correlate with the degree of engine rusting observed. For example, we have observed that with either the short trip or the dynamometer test described in the paper, oils such as D result in two to three times the ring wear than is observed using Oil A. This should not be too surprising in that numerous investigators have shown that under these conditions, ring wear is primarily a corrosion problem.*

Differences in performance of engines with respect to rusting tendencies can be accounted for by differences in engine operating temperatures, blowby rates and blowby composition. Accordingly, it is not surprising that differences in performance are observed on the road.

With respect to the question concerning the automobile industry's decision to incorporate crankcase ventilation systems on cars sold in California, I would expect the effect of these systems to vary depending on both the design and how the engine is operated. Accordingly, considerable time will be required to completely evaluate these systems. However, we have recently completed a series of service tests to evaluate the effects of present ventilation systems on engine rusting tendencies of cars in short trip passenger car operation. Based on data available to date, we see no large differences in rusting tendencies resulting from the use of crankcase ventilation systems.

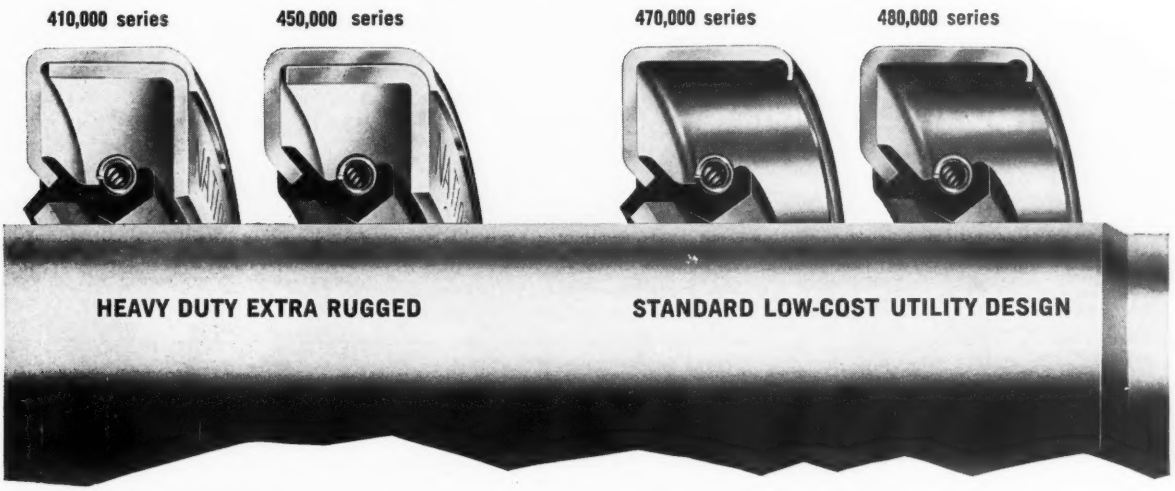
*For example, see references 6, 7, and 18 of the paper.

NATIONAL® OIL SEAL LOGBOOK

Presenting...

A rugged, dependable new shaft seal for a broad variety of applications

NATIONAL BUD* SEALS



New designs proven in 4 years of field application

Permanent bonded sealing lip, longer life, leakproof sealing

Rugged case won't distort under severe press fit

Phosphate coating avoids rust

Seal has superior concentricity

Sealing materials for temperatures —65° F to 400° F

Operates in most oils or industrial fluids

National Seal engineers — who brought you Syntech® and Micro-Torc* —now offer a ruggedly simple new advance in precision shaft sealing —National BUD (Bonded Universal Design) Oil Seals.

BUD seals are designed for a broad variety of applications, including many where more complex single-lip and double-lip designs were previously specified.

Full details and application engineering help on National BUD or other oil seals are available from your National Seal Division, Field Engineers. See the Yellow Pages under "Oil Seals" or write direct to Redwood City, Calif., home offices.

*TRADEMARK NATIONAL SEAL

NATIONAL SEAL

Division, Federal-Mogul-Bower Bearings, Inc.
General Offices: Redwood City, California
Plants: Van Wert, Ohio; Downey and Redwood City, California.

6071

If it rolls on an axle or turns in a bearing or rides on a shaft if it slides in a groove or moves on a pivot if it bores or cuts or transmits pressure one of Sinclair's 500 specialized lubricants is designed to make it work better. For answers to your lubrication problems, write today to

SINCLAIR REFINING COMPANY

Technical Service Division, 600 Fifth Ave., N.Y. 20 N.Y.

Circle No. 24 on Reader Service Card

1960 Lubrication Conference Preprint Order Form

ASLE Dept. PP
5 North Wabash
Chicago 2, Ill.

Gentlemen:

Please send me the following preprints from the Joint Lubrication Conference. Enclosed please find _____ (each preprint $.50 for members, $.75 for nonmembers).

You can save postage and handling charges by including your check or money order made payable to A.S.L.E.

_____
(Name)

_____
(Street)

_____
(City and State)

(State number of copies desired in box)

- ☐ 60LC-1. "Inhibiting Corrosive Wear In Lubrication with Halogenated Gases at 1500F by Use of Competitive Reactions and Other Methods," by Donald H. Buckley and Robert L. Johnson
- ☐ 60LC-2. "Instantaneous Coefficients of Gear Tooth Friction," by G. H. Benedict and B. W. Kelley
- ☐ 60LC-3. "Experiences with Scuffing-Test on Gear Oils in Back to Back Rigs," by G. Niemann, H. Rettig, and G. Lechner
- ☐ 60LC-4. "Evaluation of Ball Bearing Separator Materials Operating Submerged in Liquid Nitrogen," by W. A. Wilson, K. B. Martin, J. A. Brenman, and B. W. Birmingham
- ☐ 60LC-5. "The Performance of Ball Bearings in Nitrogen and Carbon Dioxide at Elevated Temperatures," by K. G. Eickhoff and A. White
- ☐ 60LC-6. "The Behavior of Lubricating Oils in Inert Gas Atmospheres," by A. Beerbower and D. F. Greene
- ☐ 60LC-7. "Orthogonally Displaced Bearing, I," by Donald F. Wilcock
- ☐ 60LC-8. "The Effect of Lubricant Viscosity and Composition on Engine Friction and Bearing Wear," by E. H. Okrent
- ☐ 60LC-9. "Friction and Wear of Metals in Gases up to 600 C," by D. F. Cornelius and W. H. Roberts
- ☐ 60LC-10. "Metallic Contact and Friction Between Sliding Surfaces," by M. J. Furey
- ☐ 60LC-11. "Development of Iron-Base Seal Materials for High Temperature Applications," by Robert J. MacDonald
- ☐ 60LC-12. "Transient Lubrication of an Accelerated Infinite Slider," by F. A. Lyman and E. A. Saibel
- ☐ 60LC-13. "A Novel Form of Self-Acting Gas Lubricated Thrust Bearing," by Amir Nahavandi and Fletcher Osterle
- ☐ 60LC-14. "A Numerical Solution for Self-Acting Gas Lubricated Full Journal Bearings of Finite Length," by A. A. Raimondi
- ☐ 60LC-15. "Pressurized Journal Gas Bearings," by John H. Laub
- ☐ 60LC-16. "Externally Pressurized Spherical Gas Bearings," by John H. Laub and Robert H. Norton, Jr.
- ☐ 60LC-17. "The Performance of Externally Pressurized Bearings Using Simple Orifice Restrictors," by D. S. Allen, P. J. Stokes and S. Whitley

Lubrication Abstracts

Edited by W. E. Campbell

Selected literature compiled by members of the Technical Committees and Industry Councils of the Society.

M. P. Volarovich, "Investigation of Piston-Cylinder and Shaft-Bearing Friction at Low Temperatures," *Wear-Usure-Verschleiss*, v. 2, no. 3, 1959, pp. 203-16.

Ten different oils and one grease are used in the study of forces versus movement of a piston in a cylinder. The results showing initial shearing force and friction force versus temperature ($-60°C$ to $+20°C$) are plotted on semilog scales. Viscosity curves for the oils are also shown as well as oscillogram photographs. The values and their relationships are explained in terms of viscosity and the thixotropic property of oils. Tests of plain bearings on a shaft cover a temperature range of $-30°C$ to $+20°C$ using six oils. Results are given showing force versus speed and displacement curves as well as friction moment versus temperature curves. By comparing calculated data to test data, the use of the Hydrodynamic Theory is justified in calculating steady state conditions of movement in sliding bearings for temperatures above $-30°C$. The test setups, equipment, and instrumentation are described. Nine references are given—seven in Russian. *(Abstractor: George C. Lawrason)*

A. B. Jones (Fafnir Bearing Co.), "Some Contribution to Ball Bearing Theory," SAE Paper S-183, March, 1959.

Ball bearings are mechanically simple structures yet the analysis of their action under service conditions presents some very difficult problems. It is shown how it is possible to calculate the internal load distribution and thus arrive at a figure which indicates the basic radial load rating for 90% probability of survival thru 1 million revolutions of the inner race. This value is designated in the bearing catalogs as the "C" value. This figure is somewhat greater than the loading a bearing is usually subjected to in practice and is actually a reference figure. However, using this figure it is possible to determine the life at any other load. Service loads are rarely the pure radial loads upon which the catalog ratings are based. More often they are composed of both radial and thrust components. The combination of these two is known as the equivalent radial lad. This load is arrived at by multiplying the actual radial load by a factor of 1.0 or 1.2 depending on whether the radial load component is fixed with respect to the outer or inner ring. Major research efforts will be required to increase our knowledge of ball bearings to answer many questions arising with the present day applications of these bearings. *(Abstractor: Weldon C Cook)*

W. C. Arnold and V. T. Stonehocker (Fairbanks, Morse and Co., Beloit, Wisconsin), W. J. Braun and D. N. Sunderman (Battelle Memorial Institute, Columbus, Ohio), "Radioactive Cylinders—A Tool for Wear Research," *SAE Journal*, v. 68, no. 5, 1960, pp. 70-75.

The problem of obtaining quick and valid cylinder liner wear measurements in large, slow-speed diesel engines is approached by selectively irradiating a liner at the point of interest only. Irradiation technique, handling and installation procedure, and method of deriving data are discussed. Some data are presented showing relative wear rates of distillate and residual fuels. Radiotracer and measured wear data are compared. *(Abstractor: George C. Lawrason)*

by F. H. Raven and R. L. Wehe, (Cornell University, Ithaca, N. Y.), "Influence of Shaft Deflection and Surface Roughness on Load-Carrying Capacity of Plain Journal Bearings," *Nasa Technical Note*, D-4, August, 1959, 54 p.

The load capacity of a full journal bearing with flexible shaft is evaluated mathematically by using the criterion of first local metallic contact. A method for determining the optimum length-diameter ratio of a bearing for maximum load capacity, based both on shaft deflection and bearing surface roughness, is given. Analytical calculations of bearing load capacity based on shaft deflections are compared with experimental capacities obtained by Battelle Memorial Institute and are shown to be of equal order by magnitude. *(NASA Abstract)*

R. A. Baughman (General Electric Company, Cincinnati, Ohio), "Experimental Laboratory Studies of Bearing Fatigue," A.S.M.E.—Paper, n. 58-A-235.

A method of studying rolling-contact fatigue is described and evaluated by correlation of specimen fatigue data with actual antifriction bearing fatigue data. The data obtained has a striking resemblance to actual bearing fatigue data and can be useful in making correlations between laboratory studies and actual bearing application. The rolling-contact rig developed for such rolling-contact fatigue studies at both room and elevated temperatures and used for obtaining these data is described. The effect of lubricant on fatigue life is reported and the importance of lubricant viscosity is indicated. *(Abstractor: R. A. Schoeppel)*

Patent Abstracts

Compiled by Ann Burchick
Aluminum Co. of America

Novel Composition of Improved Lubricating Properties Comprising a Fluorochloro Polymer, Patent #2,927,894 (D. E. Neunherz, assignor, by mesne assignments, to Minnesota Mining & Mfg. Co.) A novel lubricant composition of high load-carrying capacity consisting essentially of an admixture of a liquid open chain telometer of trifluorochloroethylene having between about 4 and 20 carbon atoms and containing a plurality of trifluorochlorethylene monomer units and chlorine terminal groups, and a diester of an aliphatic dicarboxylic acid wherein each alcohol radical contains a branched chain alkyl radical having between about 4 and 12 carbon atoms and wherein the dicarboxylic acid radical contains from 6 to 12 carbon atoms, said telometer constituting up to about 5 weight percent of said admixture.

Synthetic Lubricating Oil, Patent #2,921,-029 (W. W. Gleason, W. E. Lifson, and E. F. H. Pennekamp, assignors to Esso Research & Engineering Co.) A synthetic lubricating composition suitable for the lubrication of moving parts of combustion turbines in aircraft engines over a range of temperatures of from about 450F. to about −65F. under conditions of extreme pressure which comprises a synergestic mixture of about 2.0 to 10.0 percent by weight of tricresyl phosphate and from 98.0 to 90.0 percent by weight of a blend of esters, said blend of esters consisting essentially of from 90.0 to 95.0 percent by volume of a diester and from about 10.0 to 5.0 percent by volume of a complex ester, said diester being formed by esterifying a branched chain alcohol with a dibasic acid selected from the group consisting of sebacic and adipic acids and said complex ester being formed by esterifying 1 mol of a polyethylene glycol having a molecular weight of about 200 with 2 mols of a half ester of sebacic acid and 2-ethyl hexanol, the numerical ratio of the vol. percent of said complex ester in said blend to the wt. percent of said tricresyl phosphate in said composition is in the ratio of 1:1 to 2.5:1.

Mineral Oil Base Lubricant, Patent #2,925,-386 (W. Dietrich, Hans-Joachim Mertens and F. Wetter, assignors to Chemische Werke-Huls Aktiengesellschaft) A lubricant comprising a mineral oil base, 0.05—1% of an organic nitro compound selected from the group consisting of nitroparaffines, dinitrobenzenes, dinitrophenols, nitronaphthalenes, nitronaphthols and their halogens and C-alkyl derivatives, and 0.5—10% of an oil soluble multisulfide of a xanthogenate.

Chlorinated Hydrocarbon Ashless Detergent and Lubricating Oil Compositions Containing Same, Patent #2,926,140 (A. N. De Vault, assignor to Phillips Petroleum Co.) A process for producing an ashless lubricant additive having detergent and corrosion inhibiting properties which comprises subjecting a selected petroleum hydrocarbon fraction having a viscosity within the range of 185 to 230 SUS at 210 F., to the action of a halogenating agent selected from the group consisting of chlorine, bromine, carbon tetrachloride, carbon tetrabromide, chloroform and bromoform, under halogenating and dehydrohalogenating conditions at a temperature within the range of 375-700 F., in an amount and for a period of time sufficient to increase the viscosity of said hydrocarbon fraction at least 1.25 fold, heating the thus treated hydrocarbon fraction to a temperature of at least 500 F. to remove hydrogen halide and unstable halogen-containing compounds from the treated hydrocarbon, and recovering said additive from said treated hydrocarbon fraction.

STABLE
Dow Corning
Silicone
44 Grease
effective lubrication
from -40 to +400F
FOR FEWER TROUBLE CALLS
Dow Corning silicone lubricants have superior heat resistance . . . won't thin out, gum up or oxidize. They provide long-time lubrication even when bearing temperatures are as high as 400 F. Specify silicones wherever high temperature is a problem and "special" lubricants are required. Write today for FREE SAMPLE and literature.
Dept. 4811.
FREE SAMPLE
first in silicones
Dow Corning CORPORATION
MIDLAND, MICHIGAN

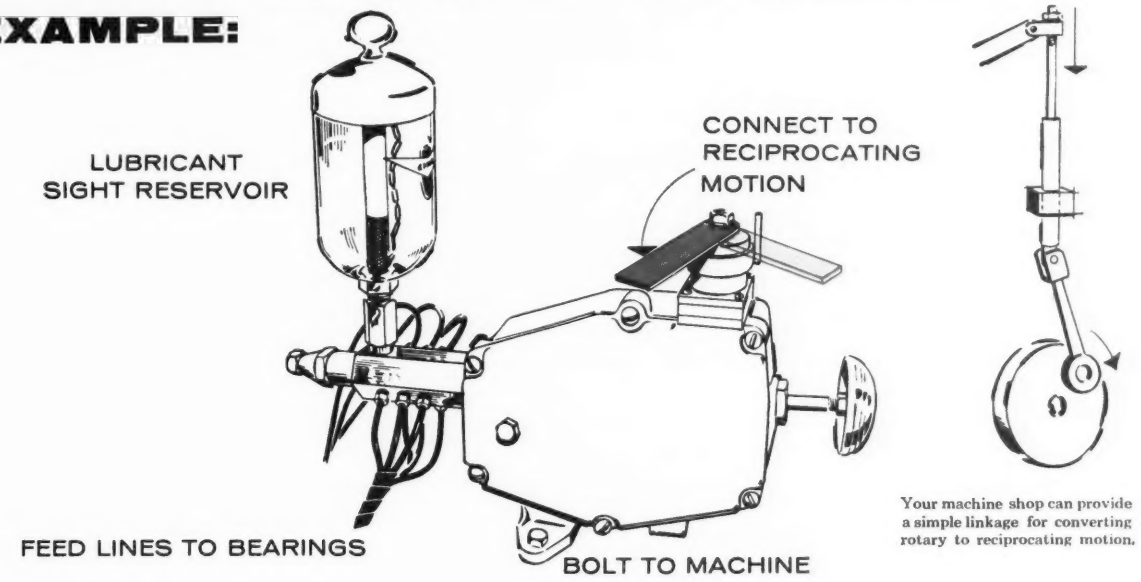
Circle No. 25 on Reader Service Card

DESIGN TIPS...on automatic lubrication

PROBLEM: **Lubricate machine tool automatically without using electricity or compressed air**

SOLUTION: **Harness reciprocating or rotary motion for positive displacement lubrication with Lincoln's ratchet Multi-Luber***

EXAMPLE:



Your machine shop can provide a simple linkage for converting rotary to reciprocating motion.

You can harness reciprocating or rotary motion on your light machine tools to provide power for automatic lubrication with Lincoln's new ratchet-operated Multi-Luber. As little as .52" straight-line motion will drive the worm gear that cycles lubricant through the Multi-Luber outlet ports to bearings.

Three operating ratios of worm gear reduction (100:1, 50:1, and 25:1) are available to satisfy requirements for any application. With standard setting, the Multi-Luber discharges 0.0025 ounces of lubricant from each port every time it cycles. Output of the first four ports can be doubled.

The ratchet Multi-Luber can overcome 2000 psi back pressure while operating. It handles light grease as well as oil and delivers an accurately-measured, predetermined amount of lubricant to individual bearings. One ratchet Multi-Luber will feed from seven to 12 lubrication points. For more than 12 points, you can use additional Multi-Luber units.

Simple to hook up, the ratchet Multi-Luber is the most versatile lubrication device available. For instance, two ratchet Multi-Luber units could be mounted on a 15-bearing machine—one to dispense grease and the other oil. Install it in any position convenient for linking the drive arm to a consistently moving part.

NOTE TO MANUFACTURERS:
Lincoln assists manufacturers in adapting automatic lubrication to either new or in-plant machines. For OEM production, contact Lincoln's Original Equipment Sales Division. For in-plant applications, contact the Industrial Sales Division.

**Trade Mark Registered*

LINCOLN ENGINEERING CO. Original Equipment Sales Division
5743 Natural Bridge St. Louis 20, Mo.

- ☐ Please send me operating data sheets on the ratchet Multi-Luber.
- ☐ Please send Catalog 50 (Multi-Luber).
- ☐ Please send Catalog 81 (Industrial Power Lubrication Systems).
- ☐ Have your representative call to advise me regarding adaptation of the Multi-Luber to my machine.

NAME_____ TITLE_____

COMPANY_____

ADDRESS_____

CITY_____ ZONE____ STATE_____

1063

LINCOLN ST LOUIS

LINCOLN
ENGINEERING COMPANY

ST. LOUIS 20, MO. • DIVISION OF THE McNEIL MACHINE & ENGINEERING CO.

Publishers Representatives

Eastern Region

ASLE
5 No. Wabash Avenue
Chicago 2, Illinois
DEarborn 2-1298

Central Region

DWIGHT EARLY & SONS
221 N. LaSalle St.
Chicago 1, Ill.
CEntral 6-2184

Western Region

McDONALD-THOMPSON
San Francisco 5, Calif.
625 Market Street
EXbrook 7-5377
Los Angeles 5, Calif.
3727 W. Sixth Street
DUnkirk 7-5391
Seattle 4, Washington
1008 Western Avenue
MA 3-3766
Portland 4, Oregon
404 Times Building
CApital 2-5146
Denver 3, Colorado
620 Sherman Street
KEystone 4-4669
Houston 6, Texas
3217 Montrose Blvd.
JA 9-6711
Dallas 19, Texas
2727 Oak Lawn Ave.
LAkeside 1-1266

POSITION AVAILABLE

Project engineer with B. S. degree in petroleum, chemical or mechanical engineering. Preferably with two to five years experience in fuel or lube oil filtration. Also desirable to have knowledge of diesel engine lube oil systems.

Excellent advancement opportunity for young engineer. Interesting challenges in developing new filtration media in research and development laboratory. Salary open. All applications confidential.

Address resume, including education, age, experience, health, preferred salary, etc. to The Briggs Filtration Company, Washington 16, D.C.

ADVERTISERS INDEX

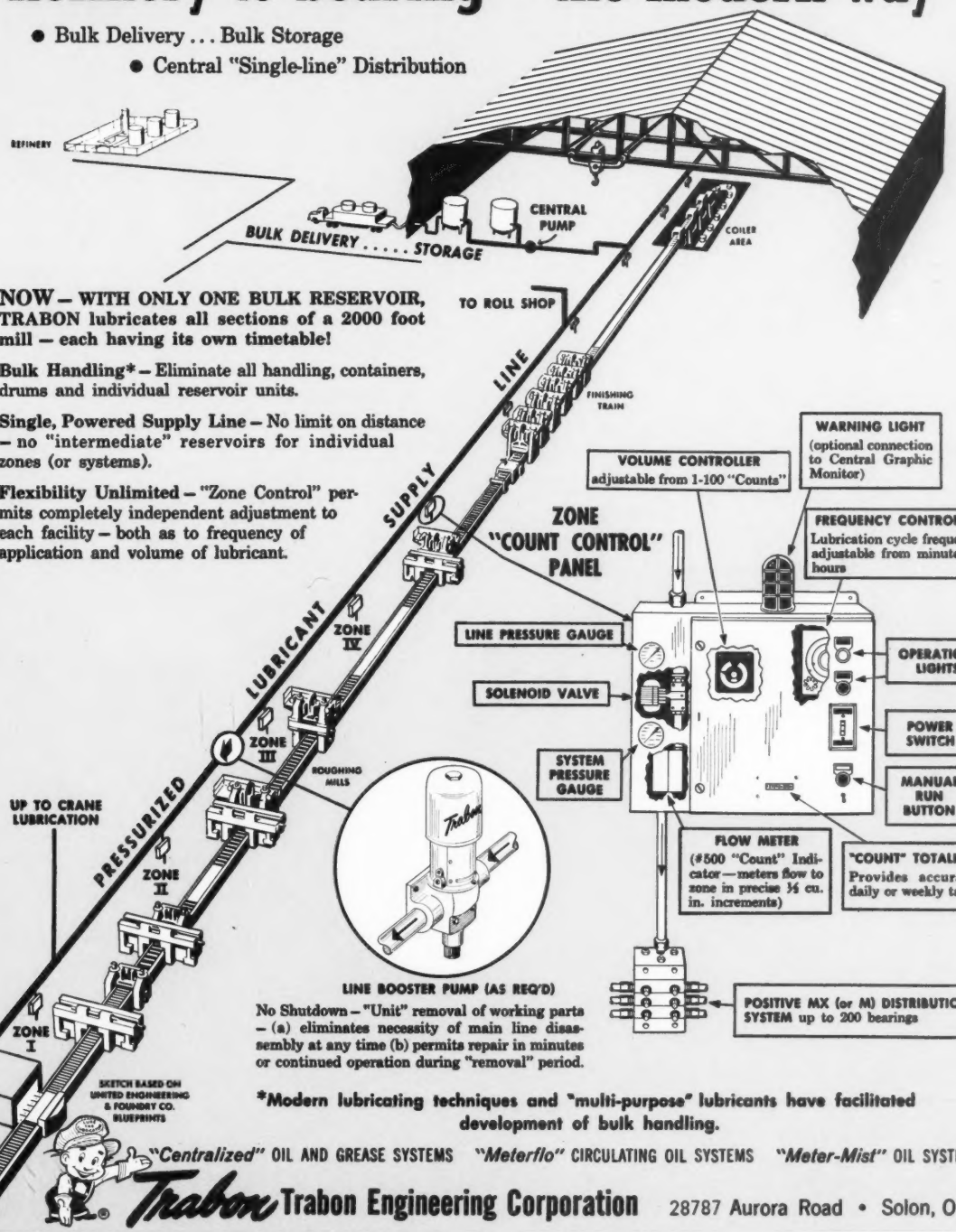
Acheson Colloids Corp. 500
Alemite Div., Stewart-Warner Corp.
Alpha Molykote Corp.
Amoco Chemicals Corp. 504
Arguto Oilless Bearing Co.
Atlantic Refining Co., The
Baroid Chemicals, Inc., A Subsidiary of National Lead Co. 510
Bemol, Inc.
Bowser, Inc.
Brooks Oil Co.
Capital Engineering and Mfg. Co.
Cities Service Oil Co. 498
Climax Molybdenum Co. 494
Commercial Solvents Corporation
D. A. Stuart Oil Co.
Dow Corning Corp. 542
Emery Industries, Inc.
Ethyl Corp.
Farval Division, Eaton Mfg. Co. ..... Second Cover
General Filters, Inc.
Grafo Colloids Corp.
Hodson Corp., The ..... Fourth Cover
Houghton Co., E. F.
Ironsides, Co., The
Joseph Dixon Crucible Co.
Lincoln Engineering Co. 543
Lubriplate Div., Fiske Bros. Refining Co.
Magie Bros. Oil Co.
Manzel Div., Houdaille Industries 509
Metal & Thermit Corp.
Meyercord Co.
Morgan Construction Co.
National Refining Co.
National Seal Div., Federal Mogul-Bower Bearing Co. 539
Norgren Co., C. A. 496
Northern Ordnance, Inc., A Subsidiary of Northern Pump Co.
Pure Oil Co., The
R. I. T. A. Corp.
Reinhold Publishing Corp.
Research Appliance Co.
Rollway Bearing Co.
Sahara Oil Co.
Shell Oil Co. 506
Simmons-Boardman Books
Sinclair Refining Co. 540
Sun Oil Co.
Trabon Engineering Corp. ..... Third Cover
Tuthill Pump Co. 493
Union Carbide Chemicals Co.
Whitmore Manufacturing Co., The 508

TRABON®

CENTRALIZED LUBRICATING SYSTEMS

Refinery to bearing—the modern way

- Bulk Delivery . . . Bulk Storage
- Central "Single-line" Distribution


REFINERY
BULK DELIVERY ..... STORAGE
CENTRAL PUMP
COILER AREA
TO ROLL SHOP
FINISHING TRAIN
SUPPLY LINE
LUBRICANT
PRESSURIZED
ZONE I
ZONE II
ZONE III
ZONE IV
ROUGHING MILLS
UP TO CRANE LUBRICATION
ZONE "COUNT CONTROL" PANEL
WARNING LIGHT (optional connection to Central Graphic Monitor)
VOLUME CONTROLLER adjustable from 1-100 "Counts"
FREQUENCY CONTROLLER Lubrication cycle frequency adjustable from minutes to hours
LINE PRESSURE GAUGE
SOLENOID VALVE
SYSTEM PRESSURE GAUGE
OPERATION LIGHTS
POWER SWITCH
MANUAL RUN BUTTON
FLOW METER (#500 "Count" Indicator—meters flow to zone in precise ⅓ cu. in. increments)
"COUNT" TOTALIZER Provides accurate daily or weekly tally
POSITIVE MX (or M) DISTRIBUTION SYSTEM up to 200 bearings
LINE BOOSTER PUMP (AS REQ'D)
No Shutdown – "Unit" removal of working parts – (a) eliminates necessity of main line disassembly at any time (b) permits repair in minutes or continued operation during "removal" period.
SKETCH BASED ON UNITED ENGINEERING & FOUNDRY CO. BLUEPRINTS

NOW – WITH ONLY ONE BULK RESERVOIR, TRABON lubricates all sections of a 2000 foot mill – each having its own timetable!

Bulk Handling* – Eliminate all handling, containers, drums and individual reservoir units.

Single, Powered Supply Line – No limit on distance – no "intermediate" reservoirs for individual zones (or systems).

Flexibility Unlimited – "Zone Control" permits completely independent adjustment to each facility – both as to frequency of application and volume of lubricant.

*Modern lubricating techniques and "multi-purpose" lubricants have facilitated development of bulk handling.

"Centralized" OIL AND GREASE SYSTEMS *"Meterflo"* CIRCULATING OIL SYSTEMS *"Meter-Mist"* OIL SYSTEMS

Trabon Engineering Corporation 28787 Aurora Road • Solon, Ohio

METALICOIL

EXTREME PRESSURE LUBRICANT

FOR SELF-CONTAINED UNITS

A compounded mineral oil of the E. P. (extreme pressure) group. Widely used for gears and bearings in connection with circulating systems and self-contained units.

METALICOIL has excellent retention at high peripherals, is water repellent and does not sludge or separate in service. Being high in film strength, it is efficient as a universal lubricant in large combination reduction sets and pinions as well as on auxiliary table, hot bed and furnace drives.

METALICOIL is furnished in a wide range of viscosities. Used in pinions, reduction sets, auxiliary drives, cranes, tables, hoists, bridges, locks, industrial trucks and in bridge and hot metal car journals.

HODSON

The HODSON CORPORATION

Lubrication

5301-11 West 66th Street

CHICAGO 38, ILLINOIS

Product name METALICOIL is a registered trade mark of
The Hodson Corporation

11-L-60

Printed in U.S.A.